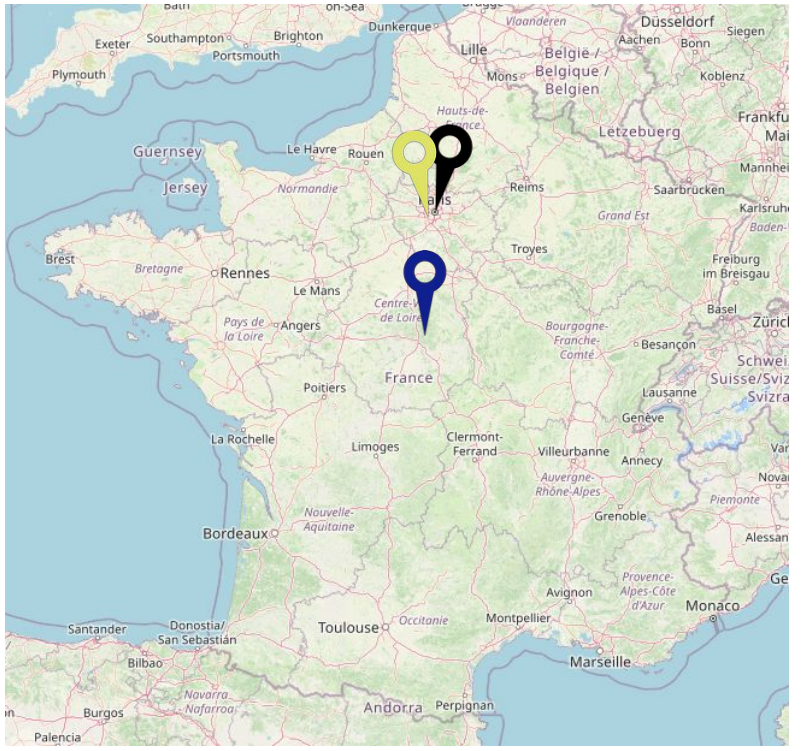
Applications WR en radioastronomie

Cedric Dumez-Viou
Observatoire Radioastronomique de Nançay

Workshop Synchronisation de précision et Réseaux, 2024/10/02

Introduction

- ORN (Service Scientifique obspm, UAR) :
  - R&D instrumentale
  - Maintenance en production d'un parc de radiotélescopes
- Outline
  - La **radio**astronomie
  - L'instrumentation « classique »
  - Apport de WR à l'instrumentation



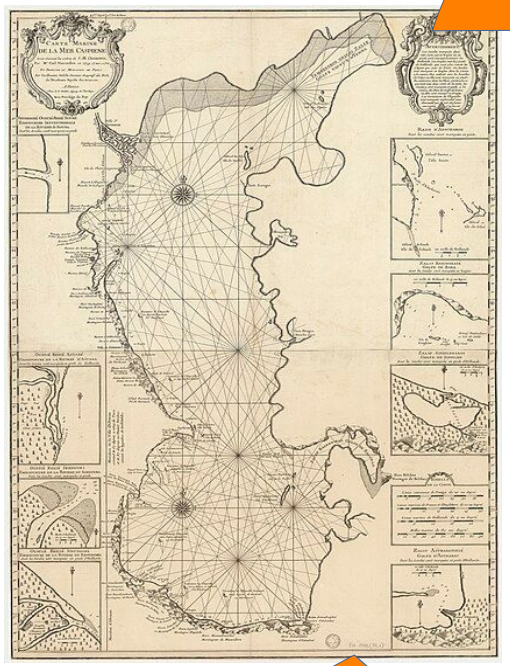
Observatoire de Paris | PSL | cnrs

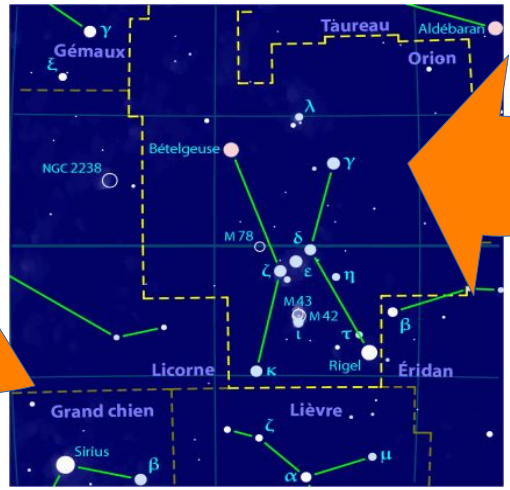
L’astronomie, le temps et l’espace

Vieil historique d’amélioration continue du triplet Ciel/temps/Espace

Qques jours → agriculture

Qques secondes → navigation





White Rabbit
COLLABORATION

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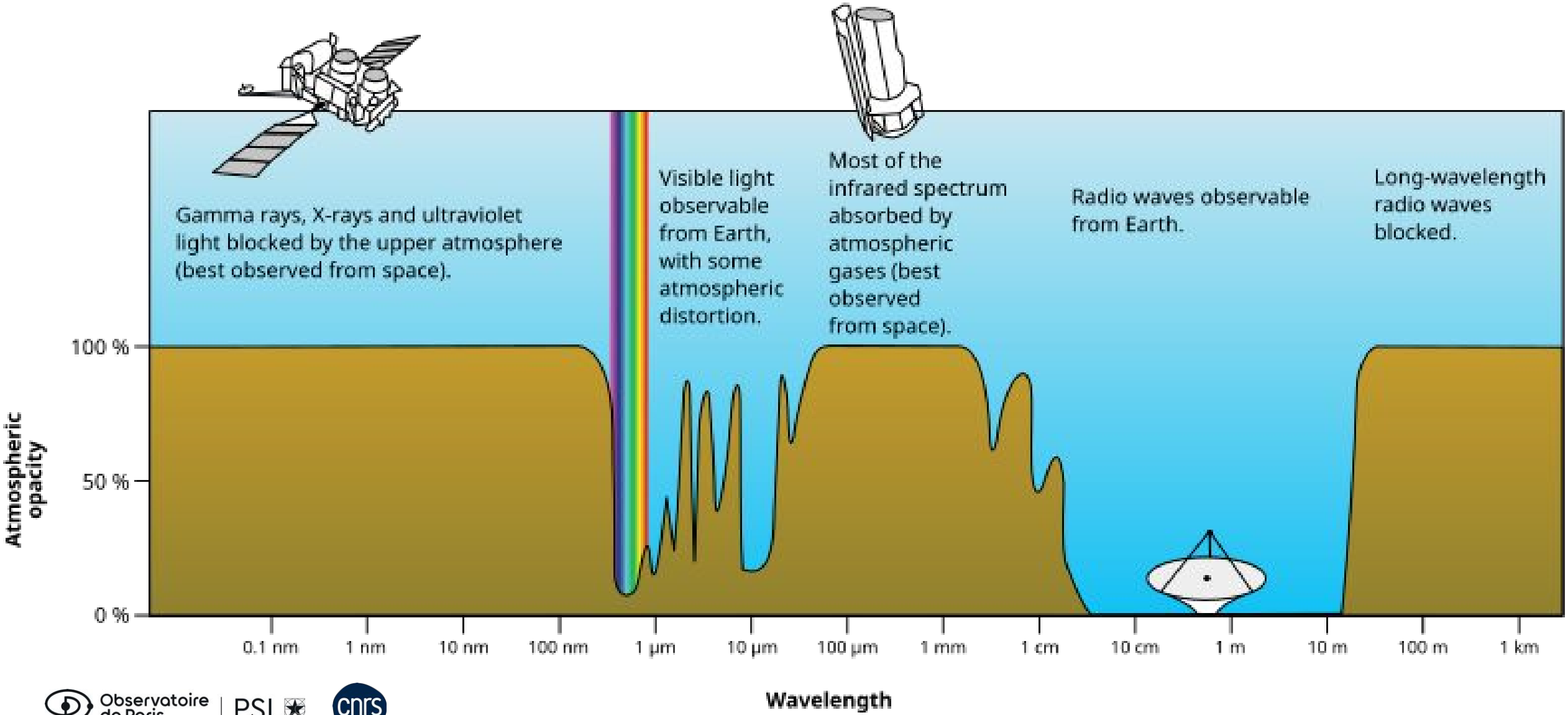
La Radioastronomie



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Les sources et phénomènes

Sources :

- Étoiles (dont le Soleil)
- Planètes (magnétisées)
- Comètes
- Nuages de gaz (chauds, froids)
- Pulsars
- Galaxies
- Masers/Megamasers
- Quasars

Phénomènes :

- Émission thermique
- Émission non-thermique
  - Raies spectrales
  - Bremßtrahlung/synchrotron
- Absorption (de raies spectrales)

MENU

BASS2000
BAse de données Solaire Sol
Solar Survey Archive

327 MHz

Previous day | 30/09/2024 | OK | Next day

Enter a date: Ex: 28/3/2001, 28.3.1, 28-3-01,YYYYMMDD or YYMMDD

LATEST OBSERVATIONS

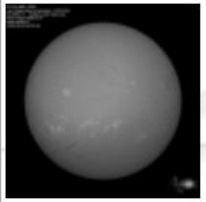
METEOSPACE

30-Sep-2024 15:00:09
H Alpha image

.jpg
.fts.fz
movie
solar grid

.jpg

CLIMSO PIC DU MIDI



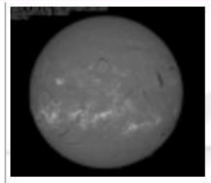
30-Sep-2024 09:00:50
H Alpha image

.png
.fts
movie
C1/L1 surimpose

30-Sep-2024 09:00:50

.png

SOLEX: THE SOLAR E



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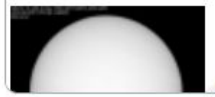
H Alph



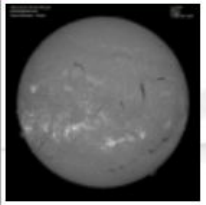
29-Sep-20
H alpha blu

USET-ROYAL OBSERVATORY OF BELGIUM

29-Sep-2024 08:02:05
H Alpha image

.jpg
.fts
solar grid

MEUDON SPECTROHELIOGRAPH



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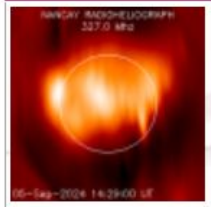
H Alpha image

.jpg
.fits.gz
3D datacubes
image with grid

28-Sep-2024 08:20:03

.jpg

NANCAY RADIOHELIOGRAPH

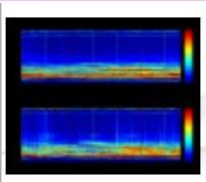


05-Sep-2024 14:29:00
327Mhz radio image

.png
.fits
movie plots
32/10s 128/120s

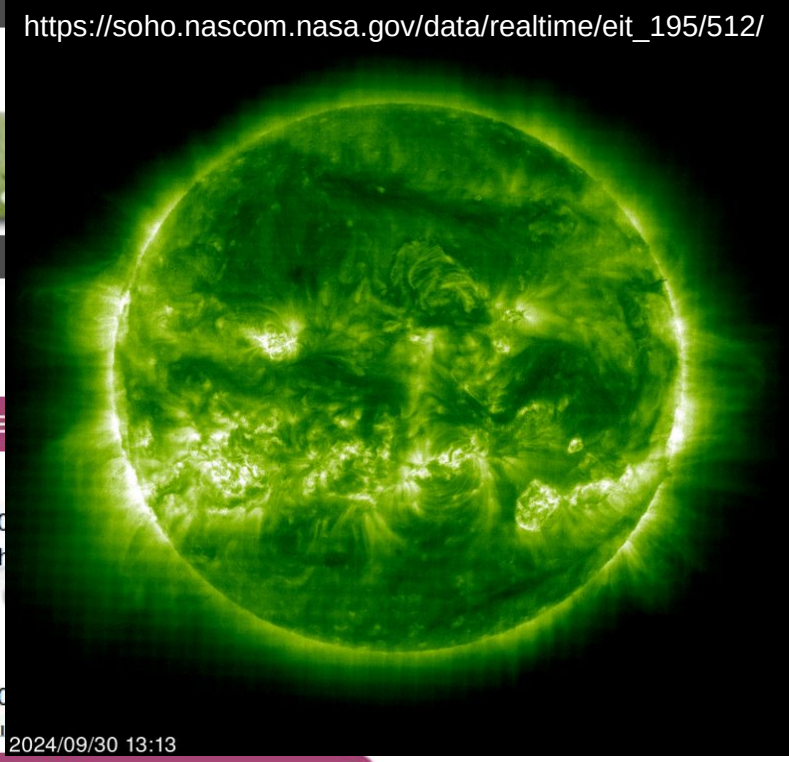
.png

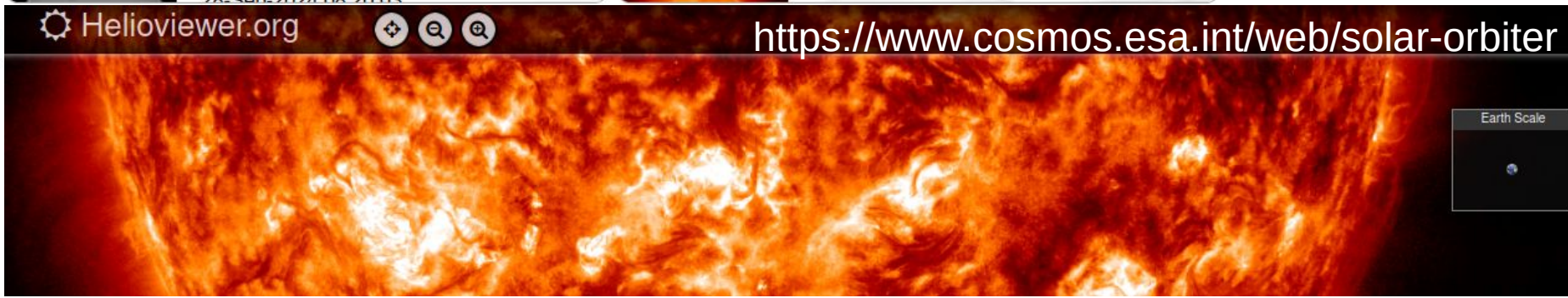
NANCAY DECAMETRIC ARRAY

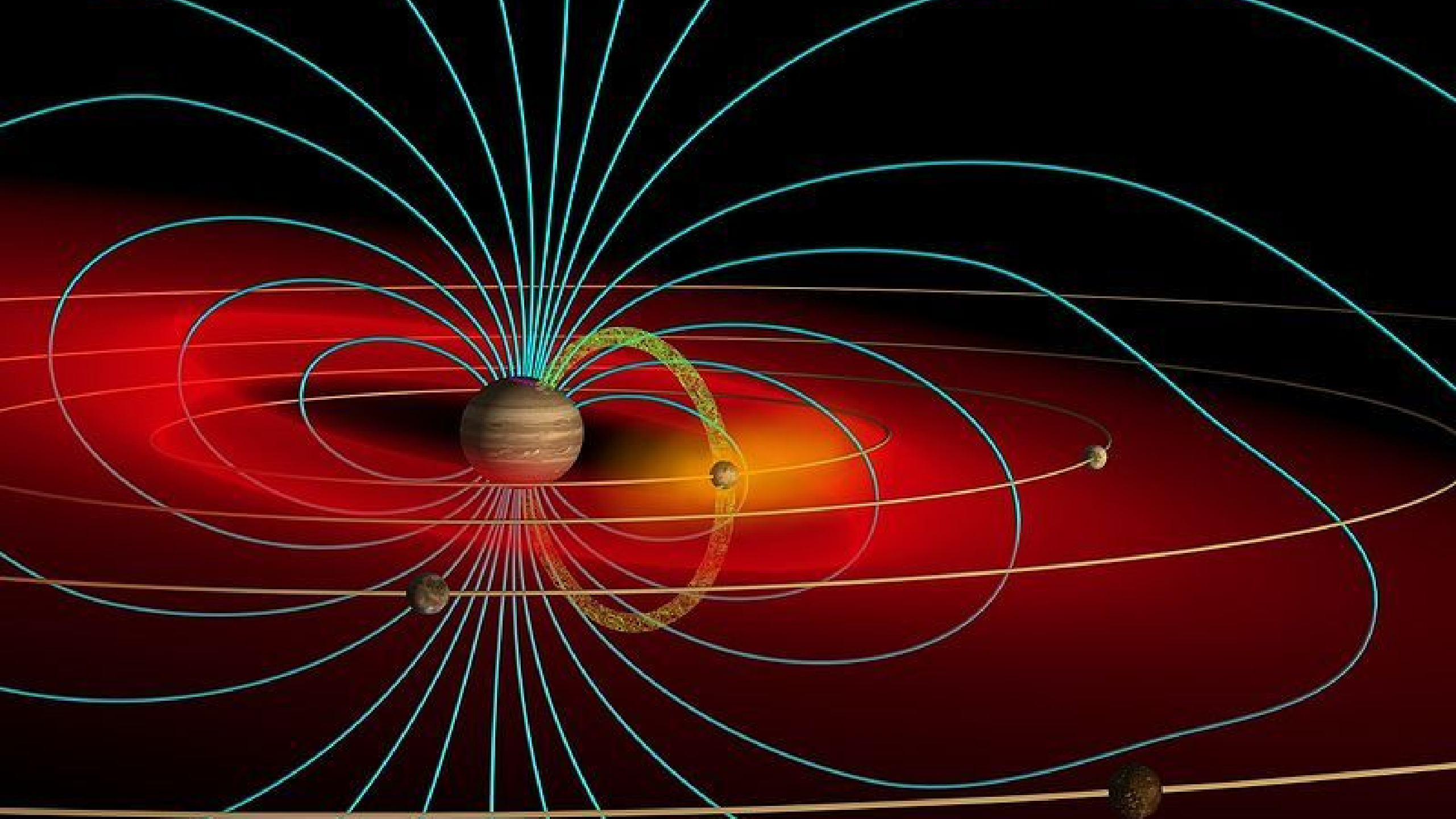


29-Sep-2024
Full resolution dynamic spectra with polarization

.png
.RT1







STRUCTURE D'UNE COMETE

Queue de plasma
Longueur : jusqu'à ~100 millions km

Queue de poussières
Longueur : jusqu'à ~10 millions km

Enveloppe d'hydrogène
Longueur : jusqu'à ~10 millions km

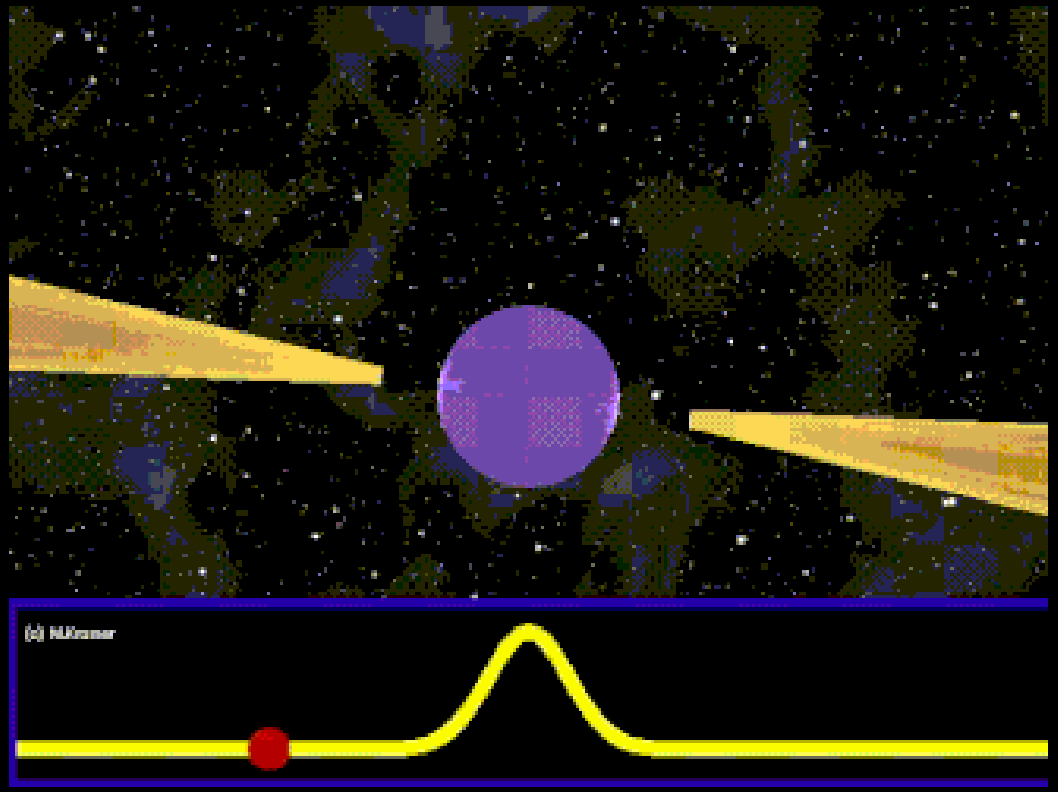
Noyau
Diamètre de quelques km à quelques douzaines de km

Chevelure (ou coma)
Diamètre : jusqu'à 1 million km


Comète 153P/Ikeya-Zhang

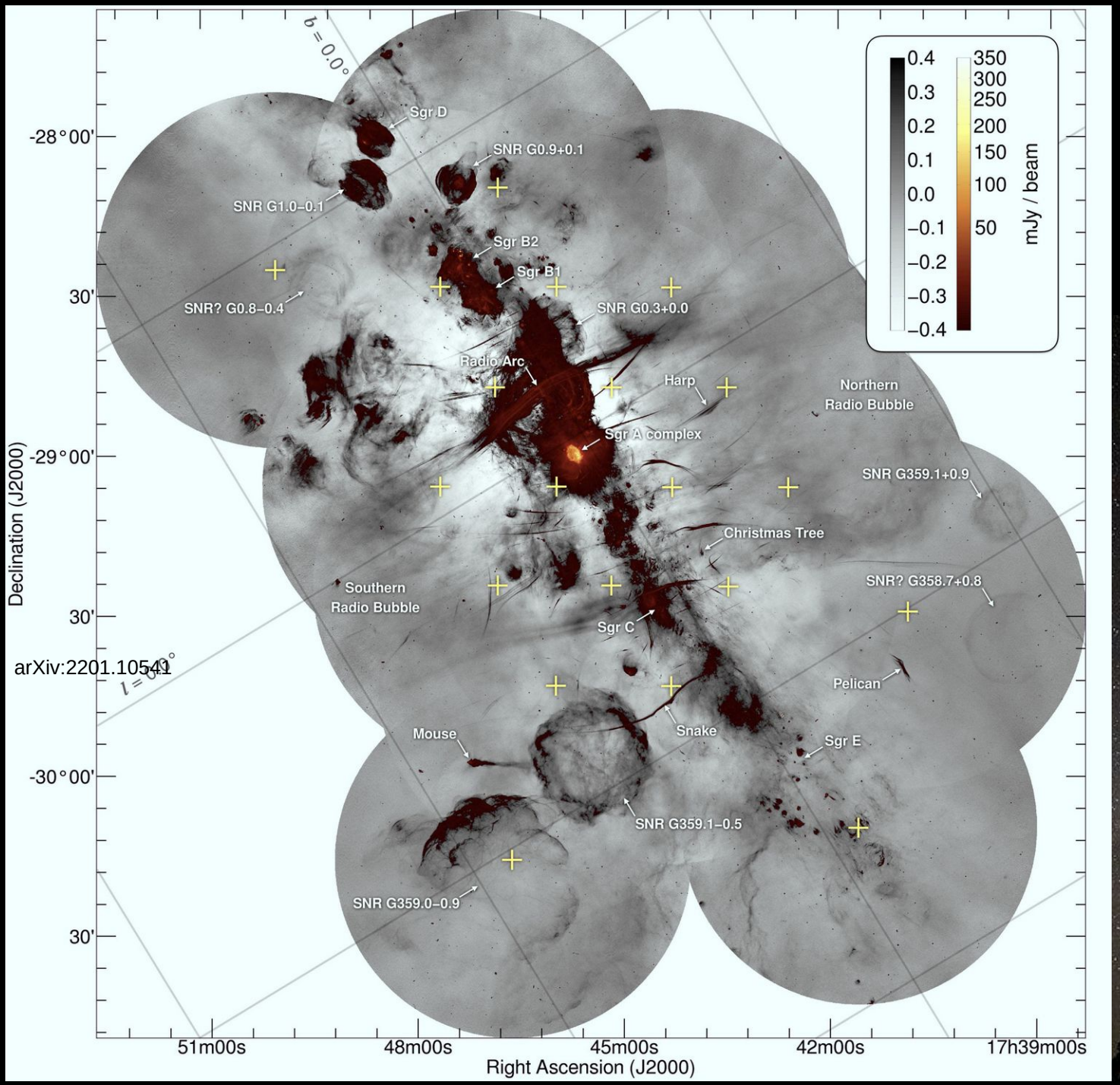

Comète Hale-Bopp


Comète NEOWISE



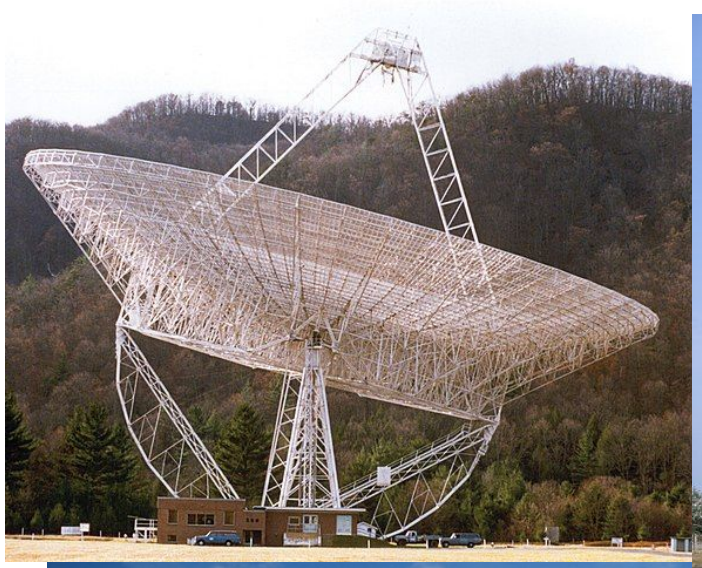
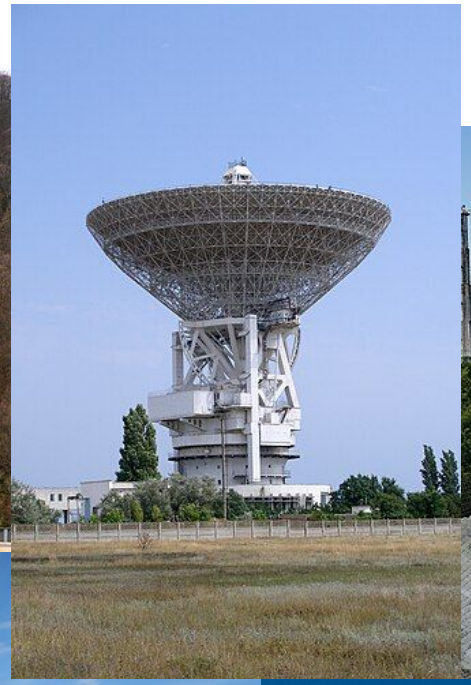
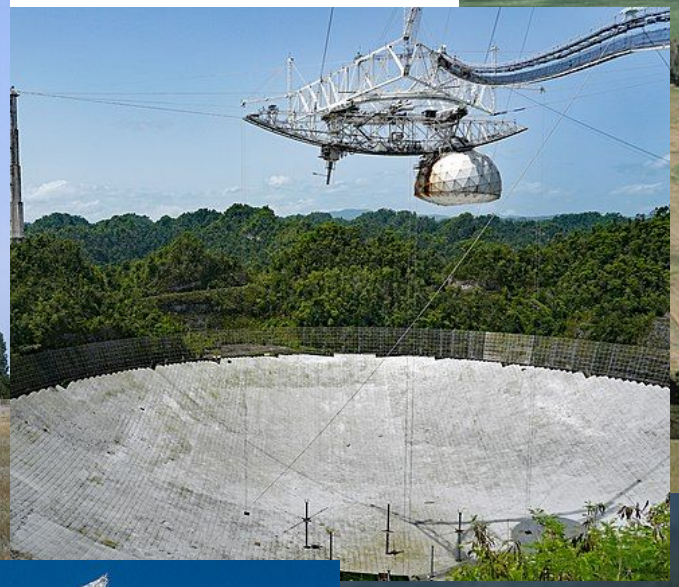
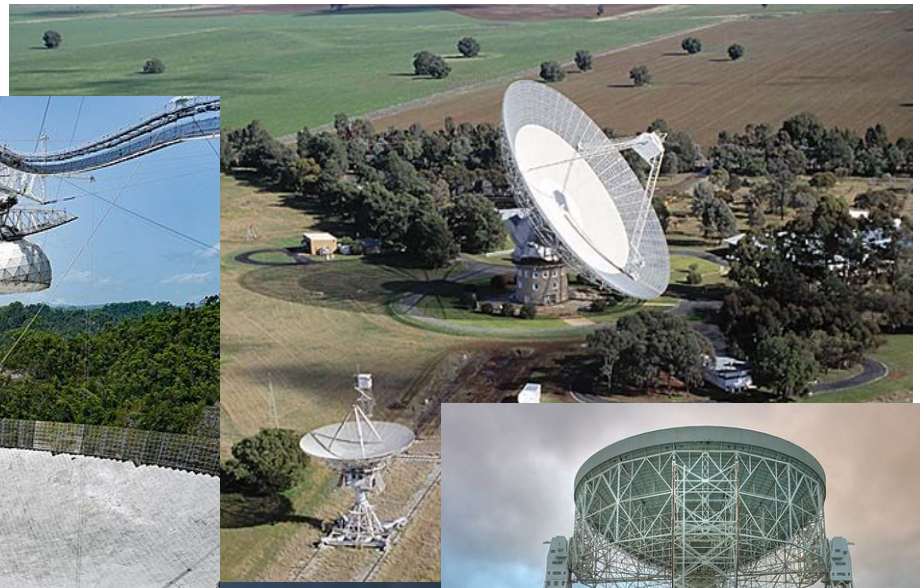
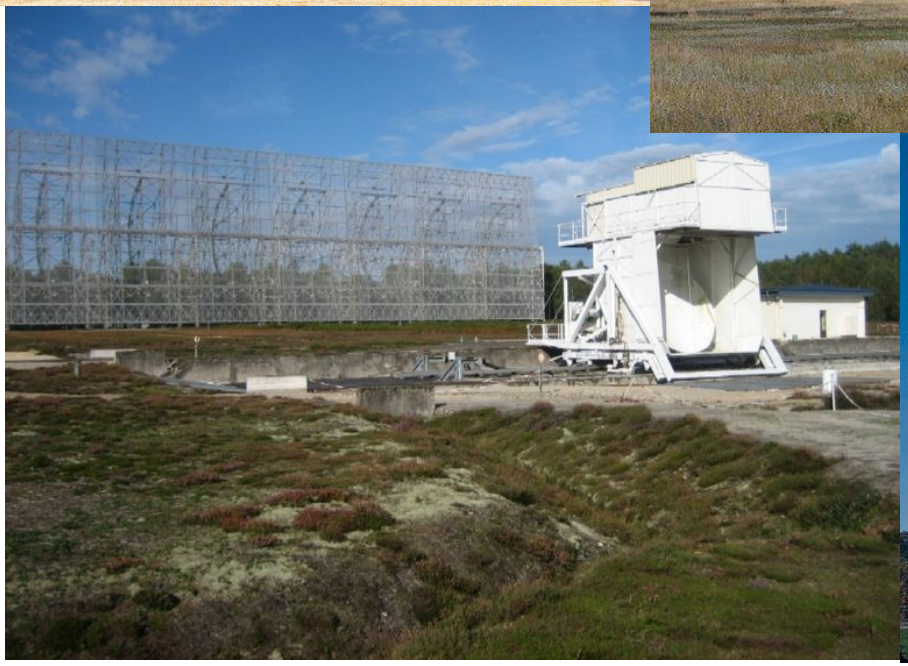
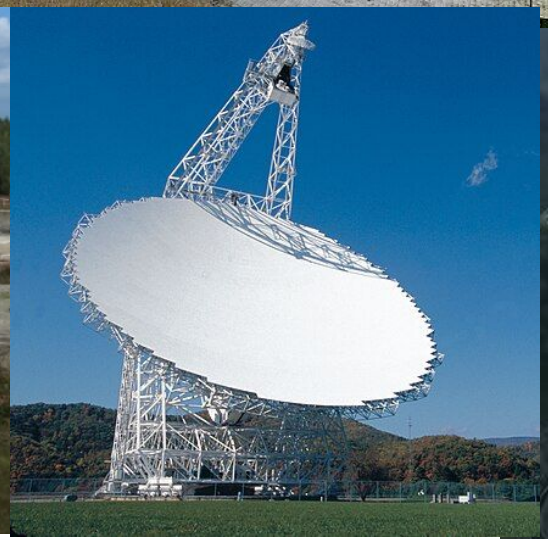
Visible

Fermi Gamma-ray Space Telescope

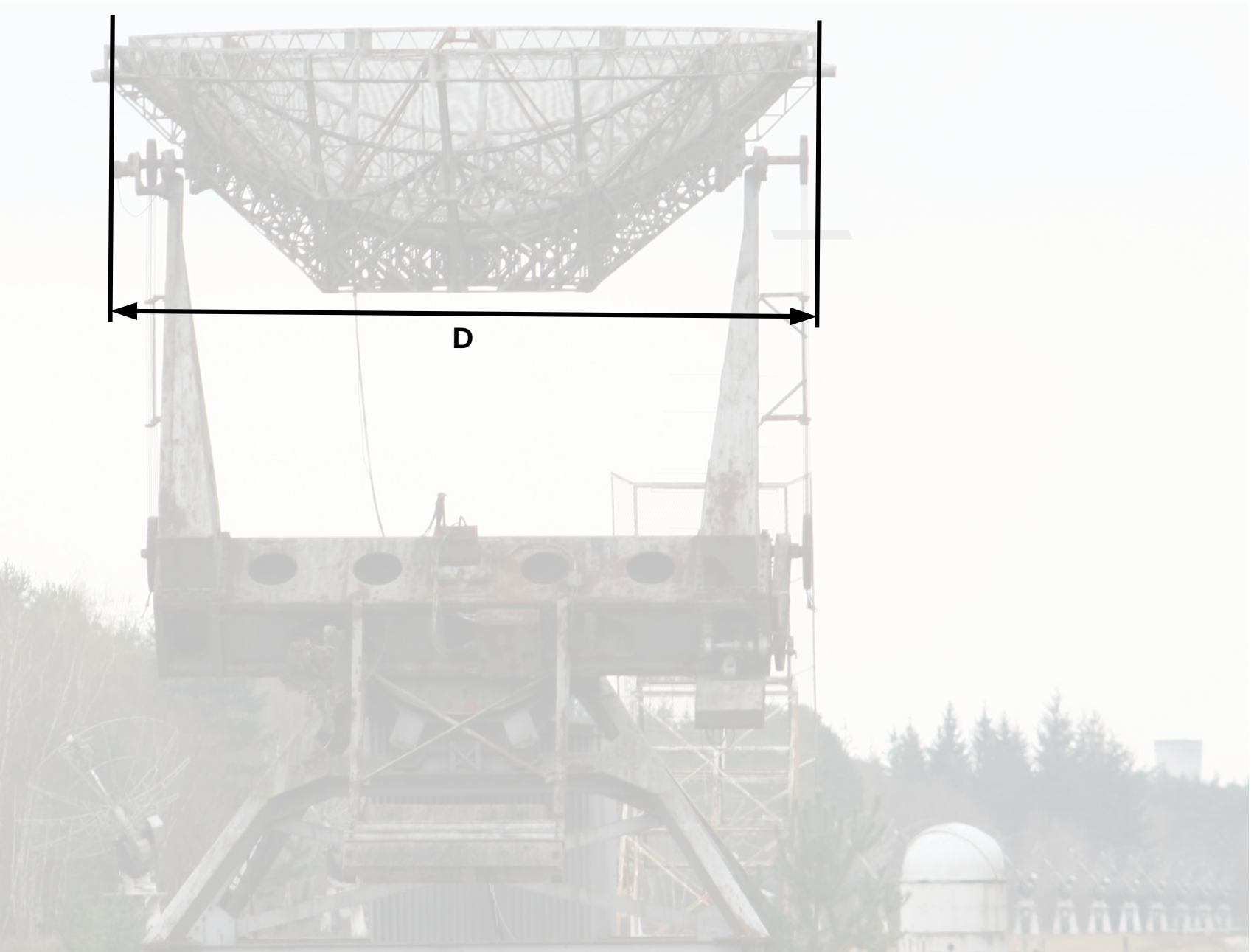


arXiv:2201.10541

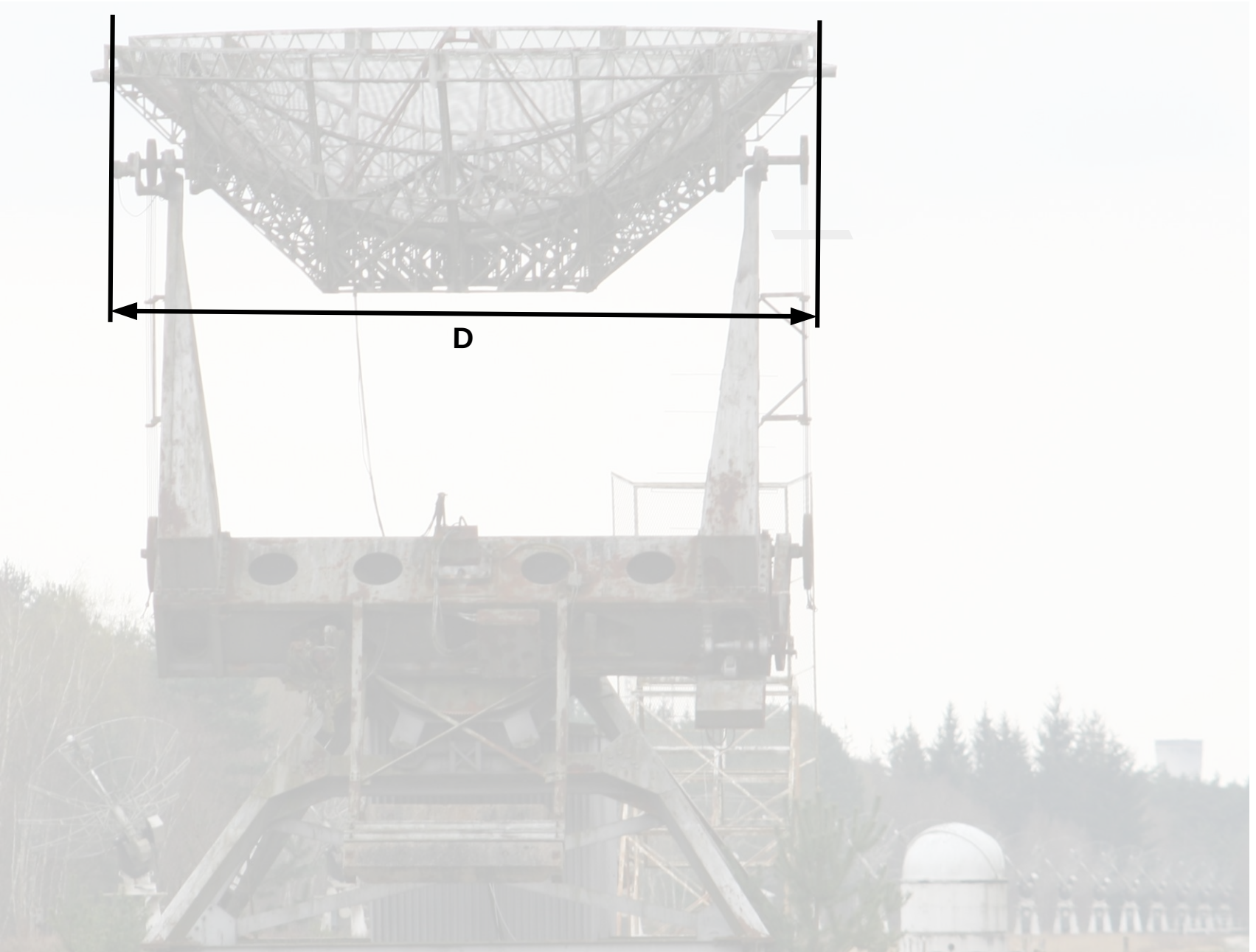
Les radiotélescopes de « classe-100 »


D


D

Large collecting area
→ sensitivity $\propto D^2$



Large collecting area

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Large extension

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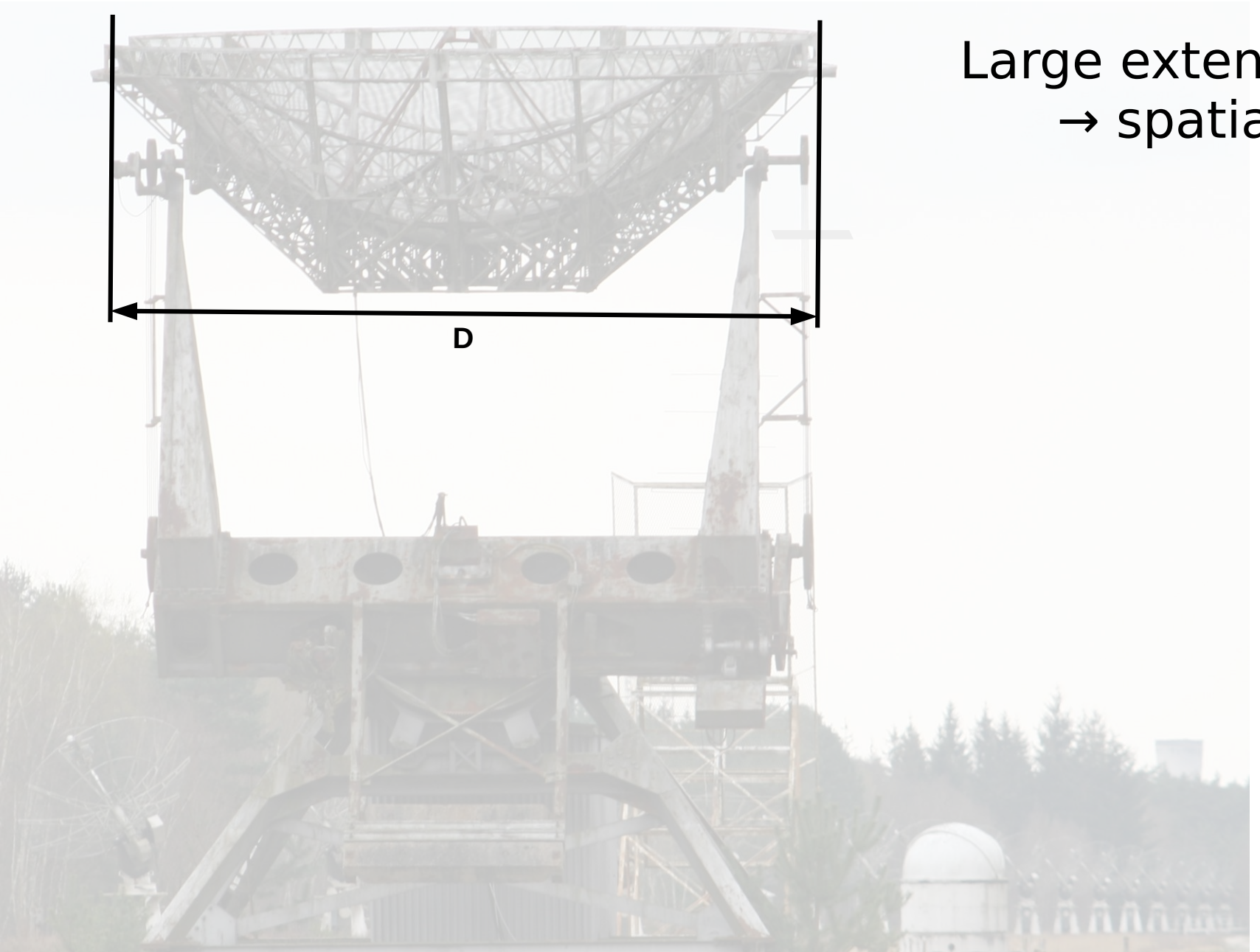

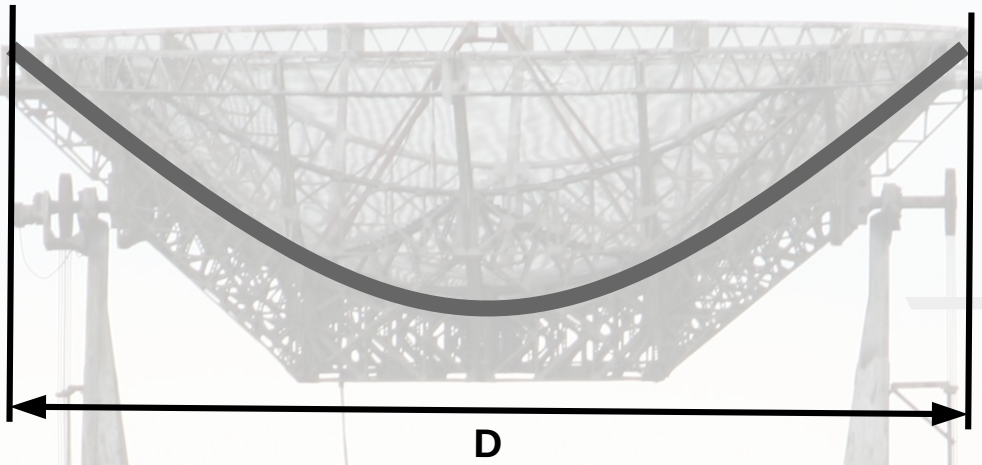

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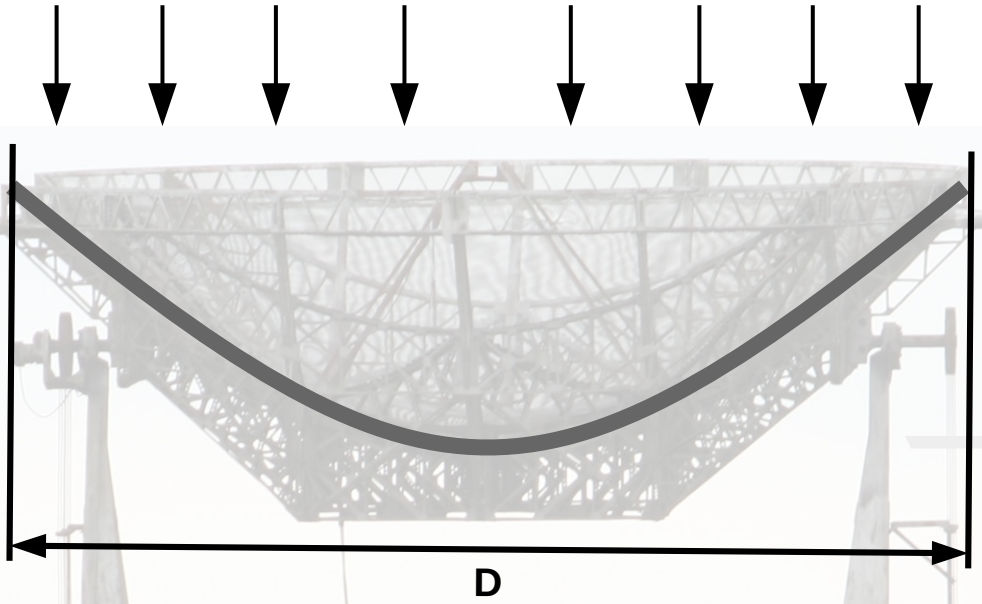
Phasing « precision »
→ Surface Roughness $< \lambda/10$



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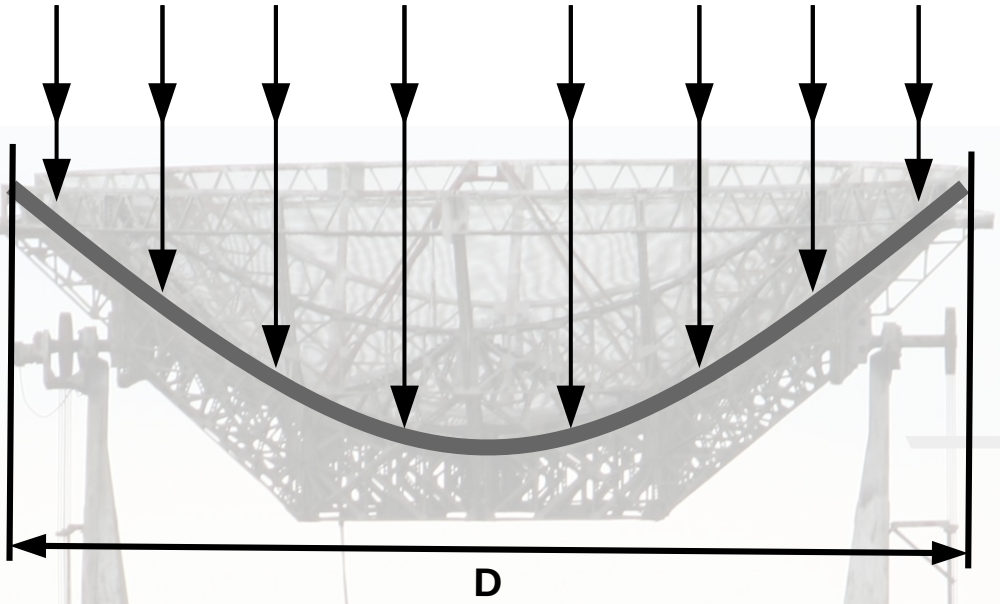

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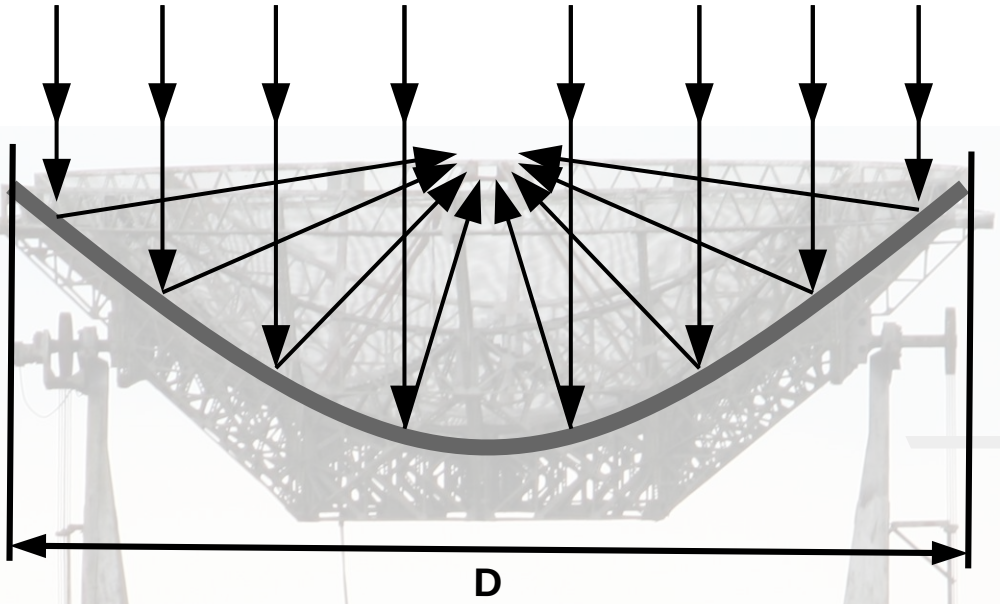

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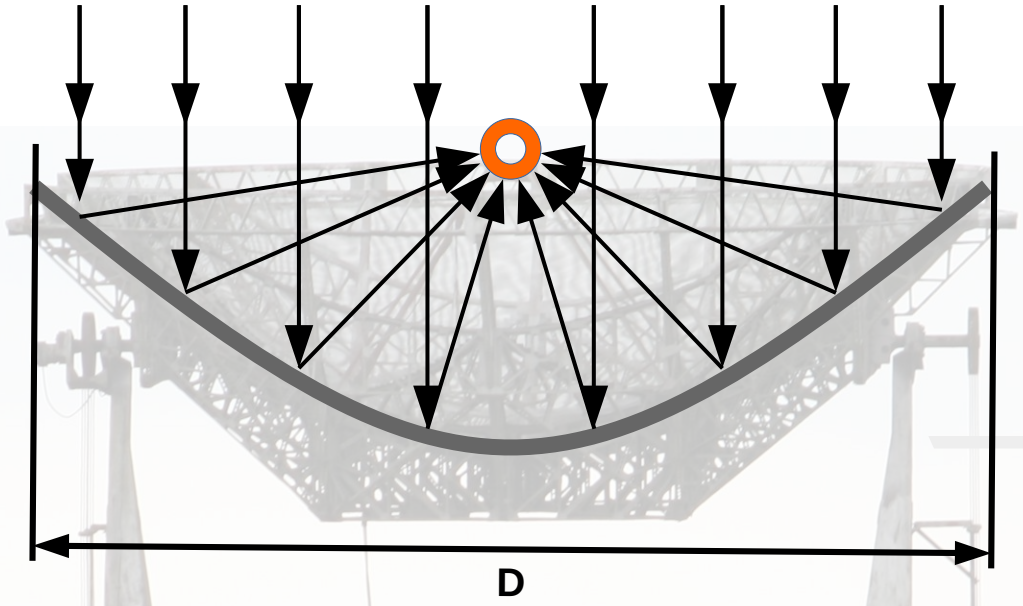

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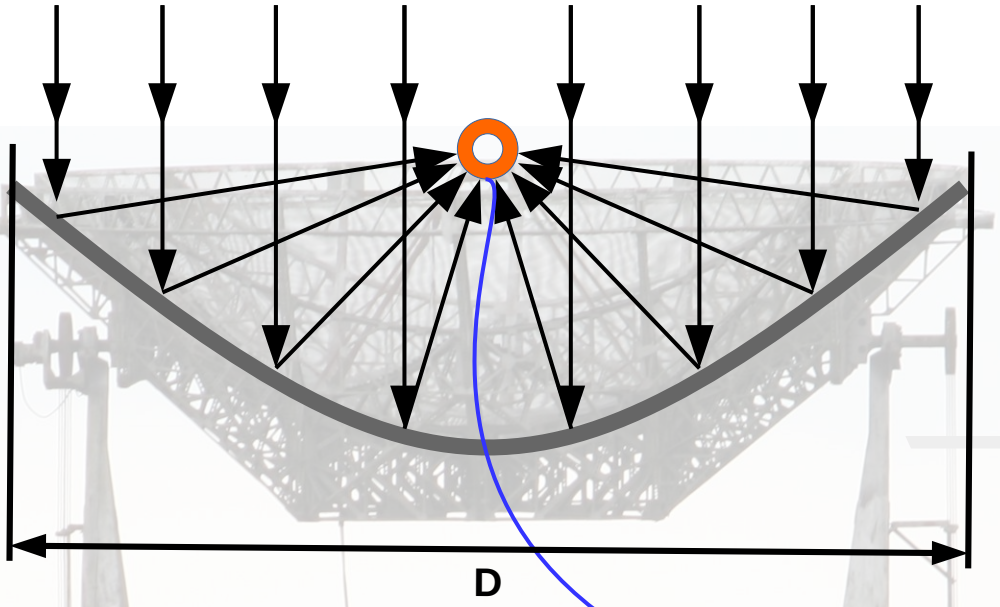

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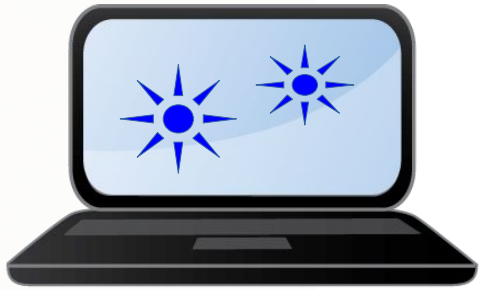

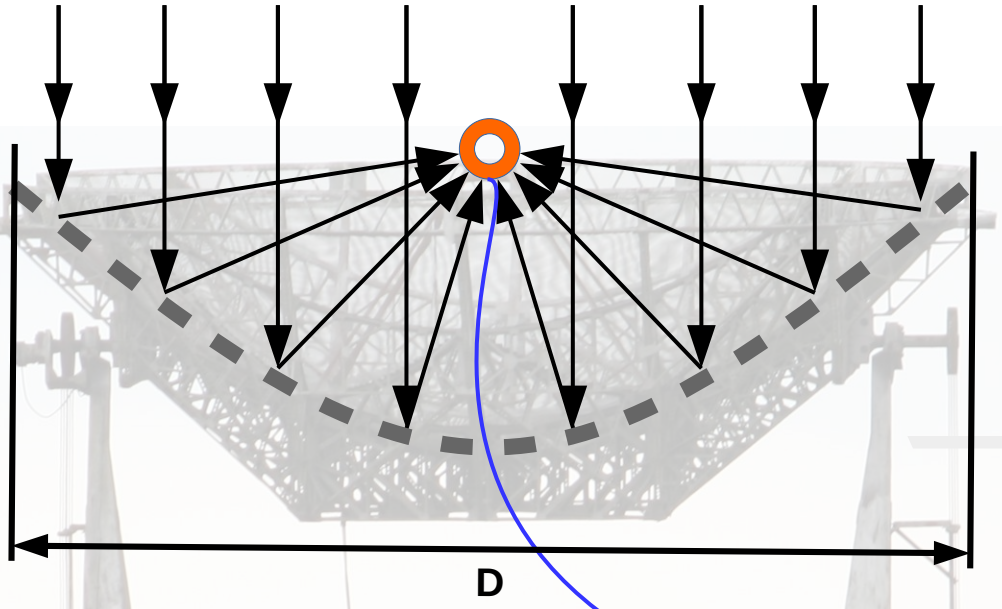

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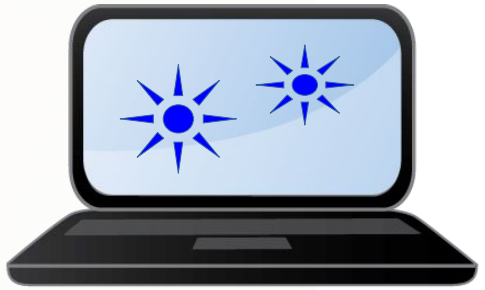

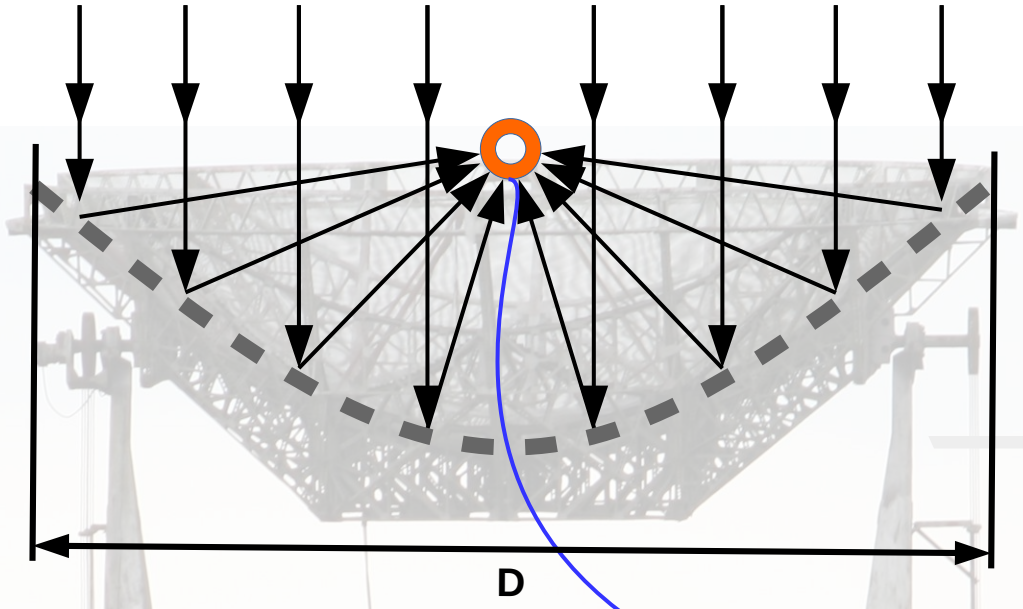

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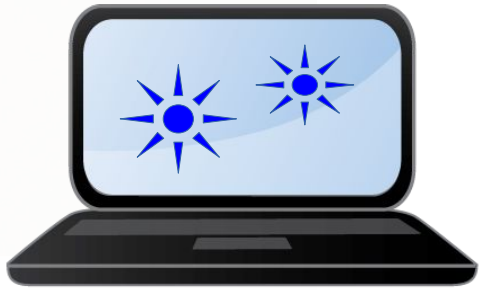

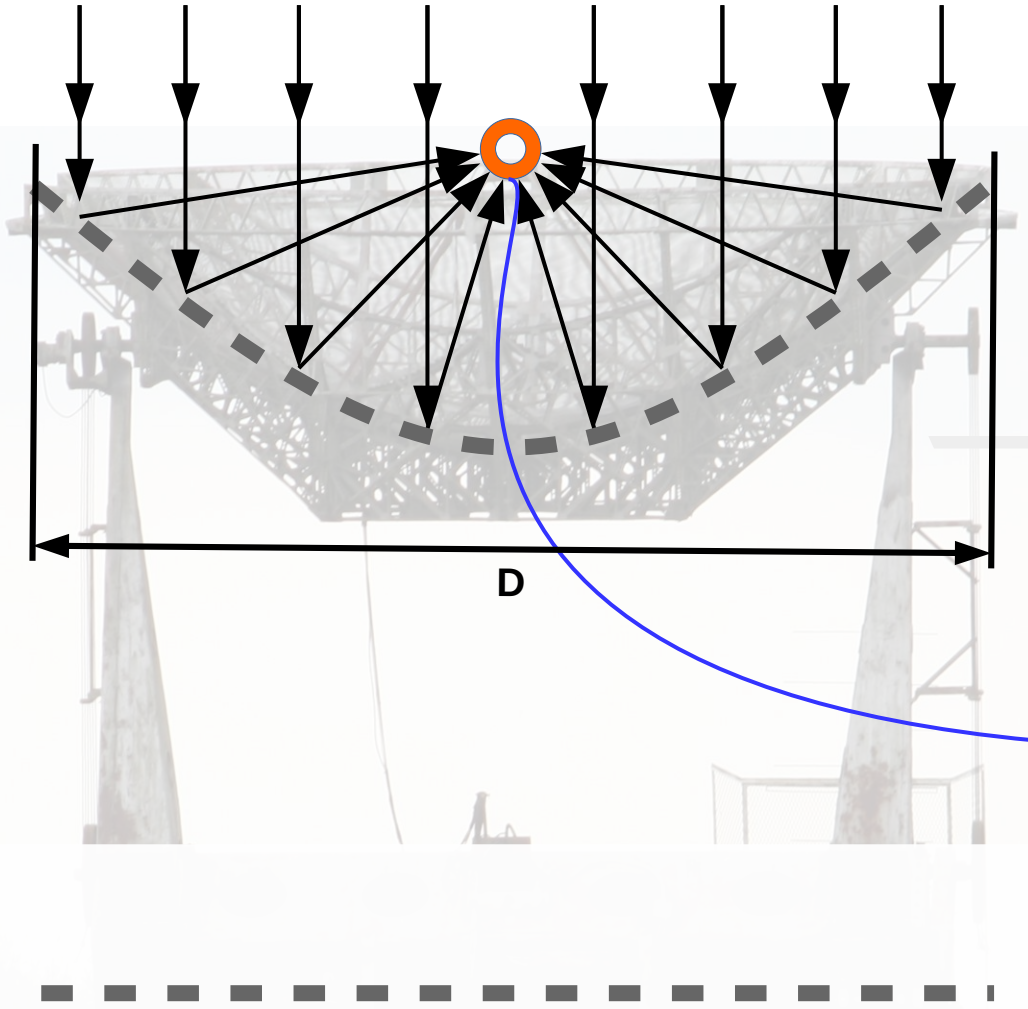

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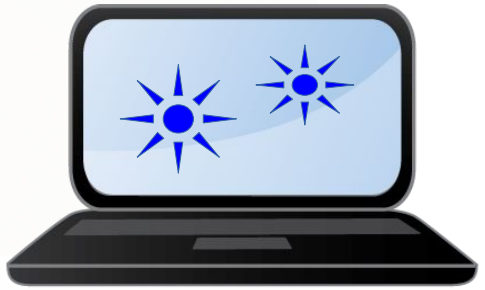

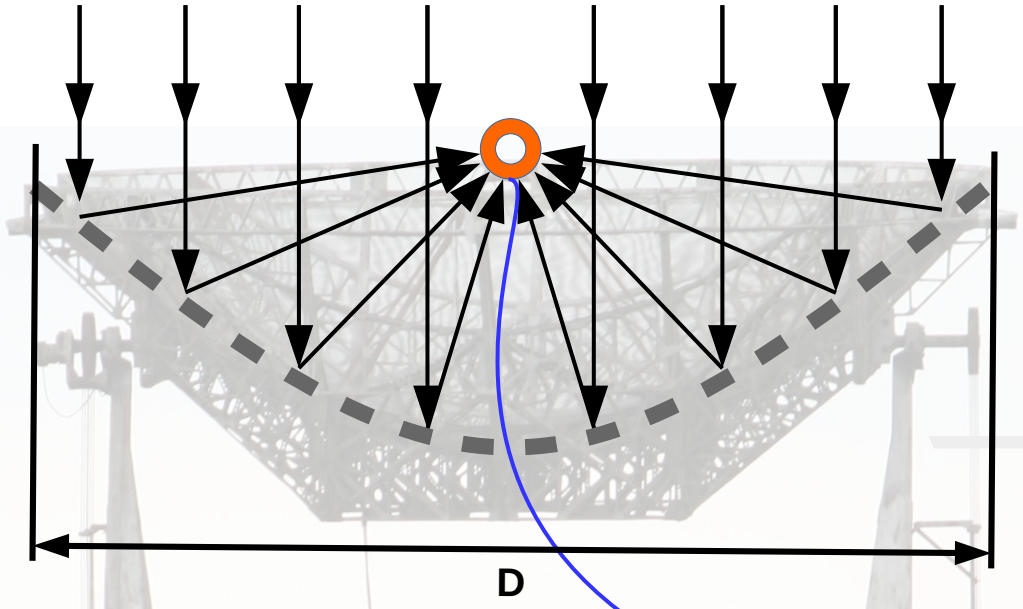

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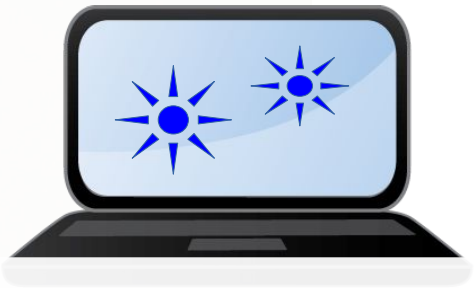

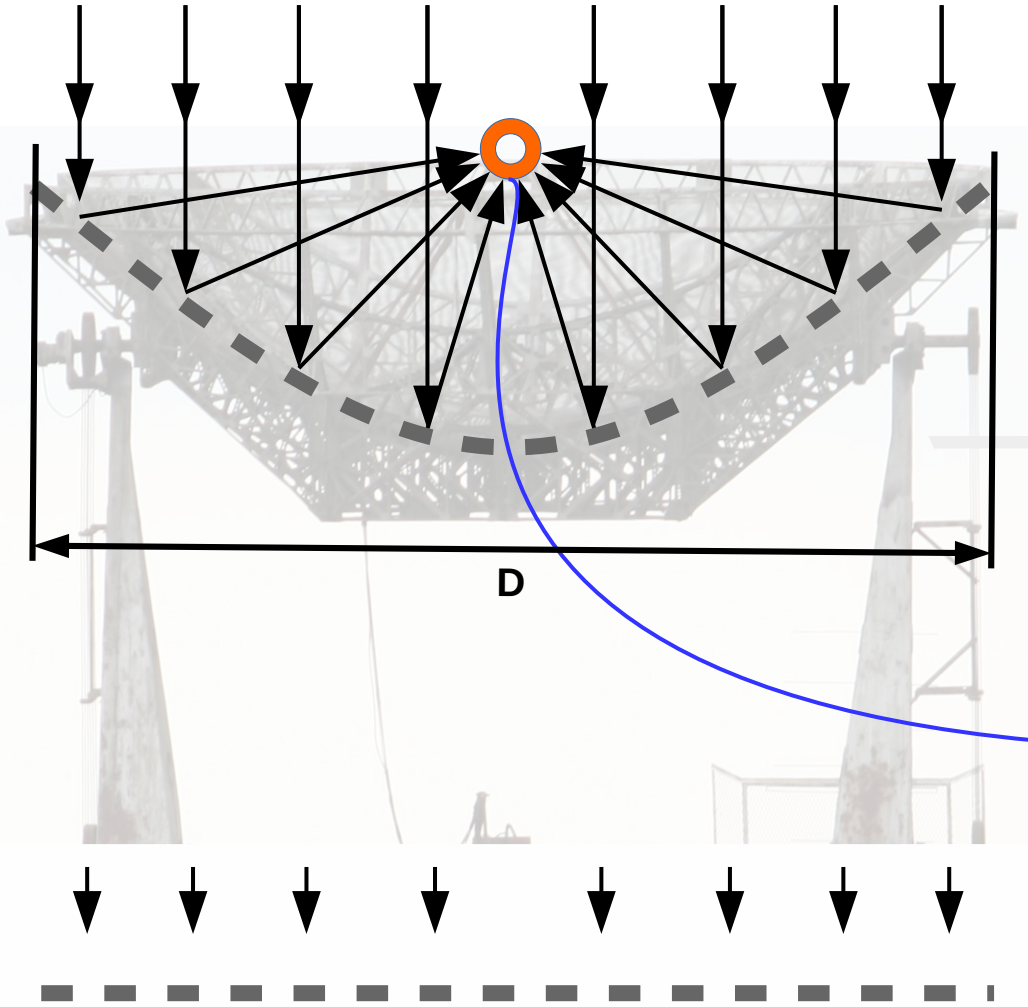

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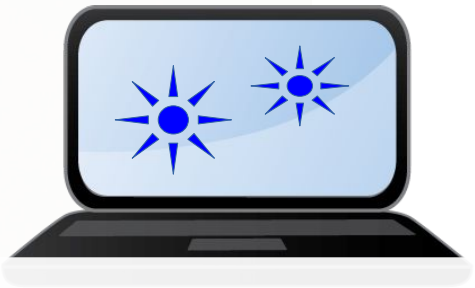

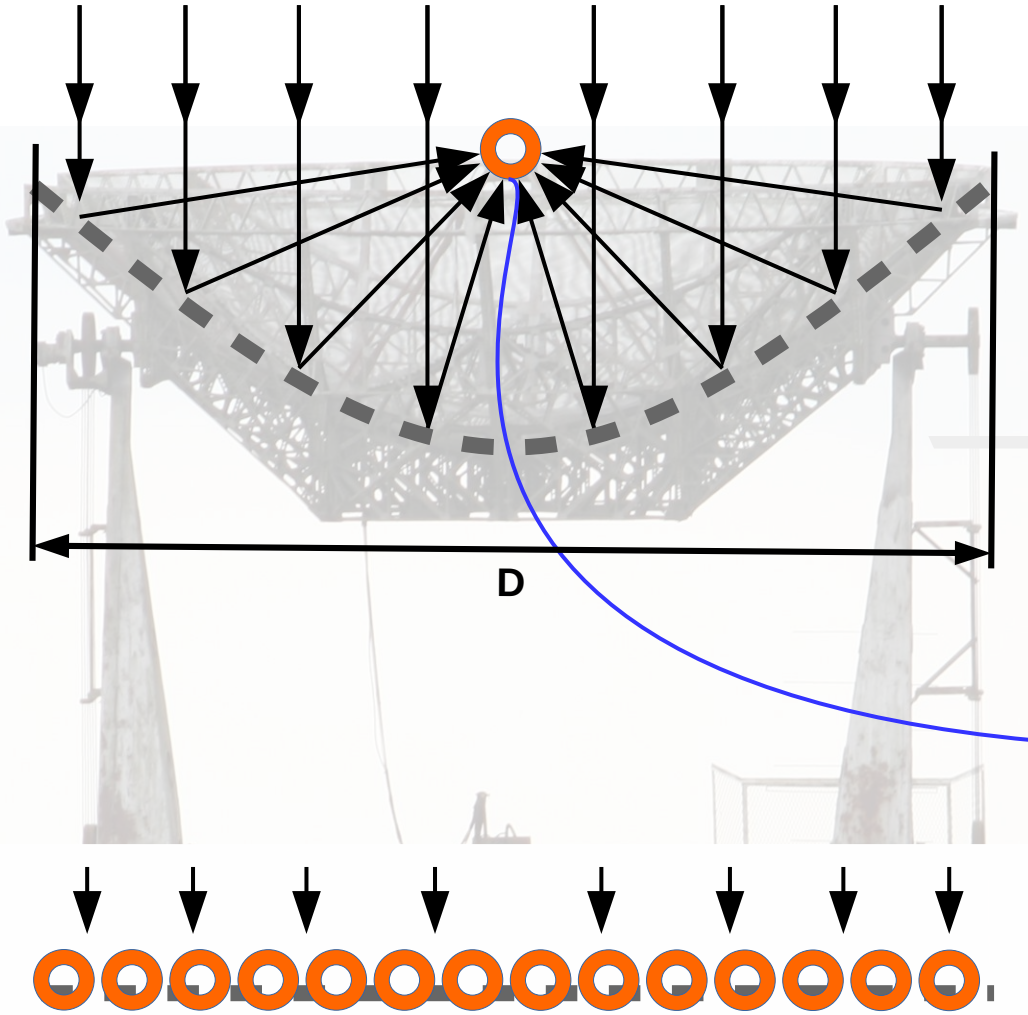

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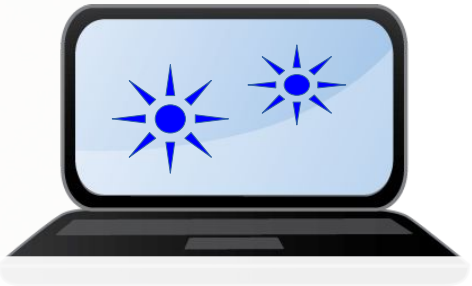

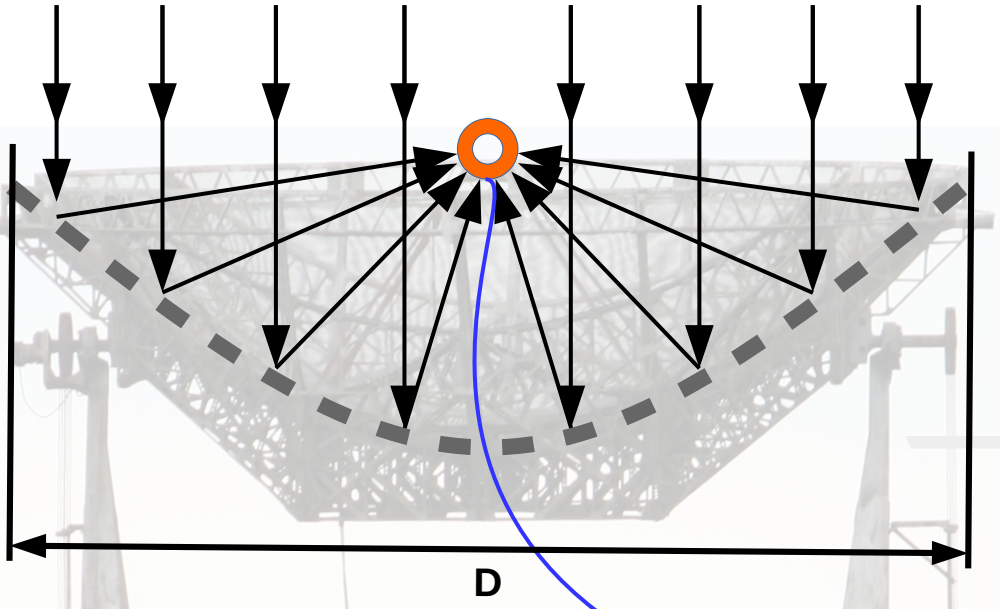

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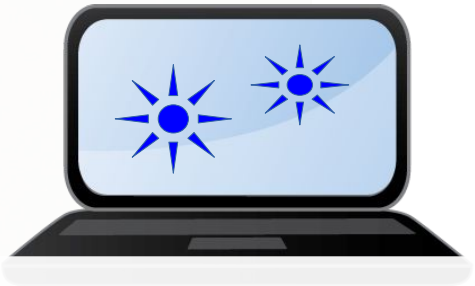

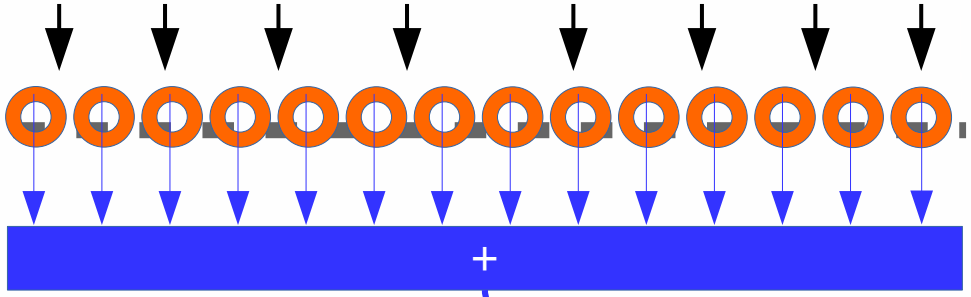

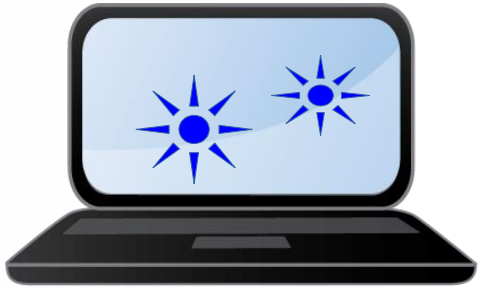

Beamformer / Synthèse de faisceau

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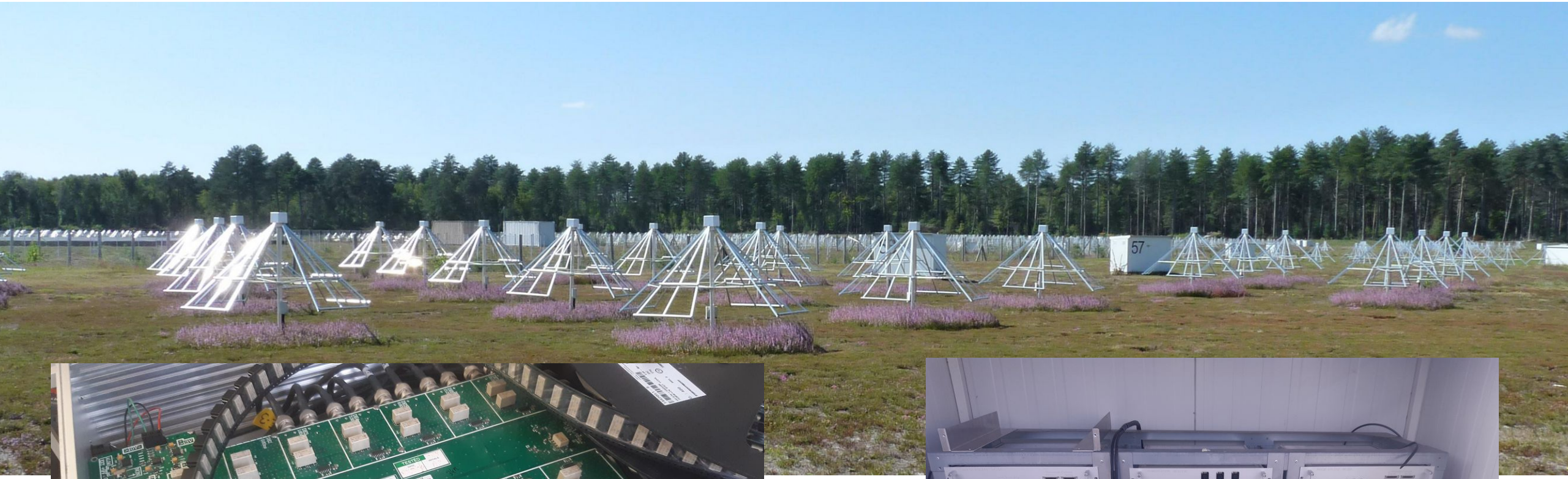

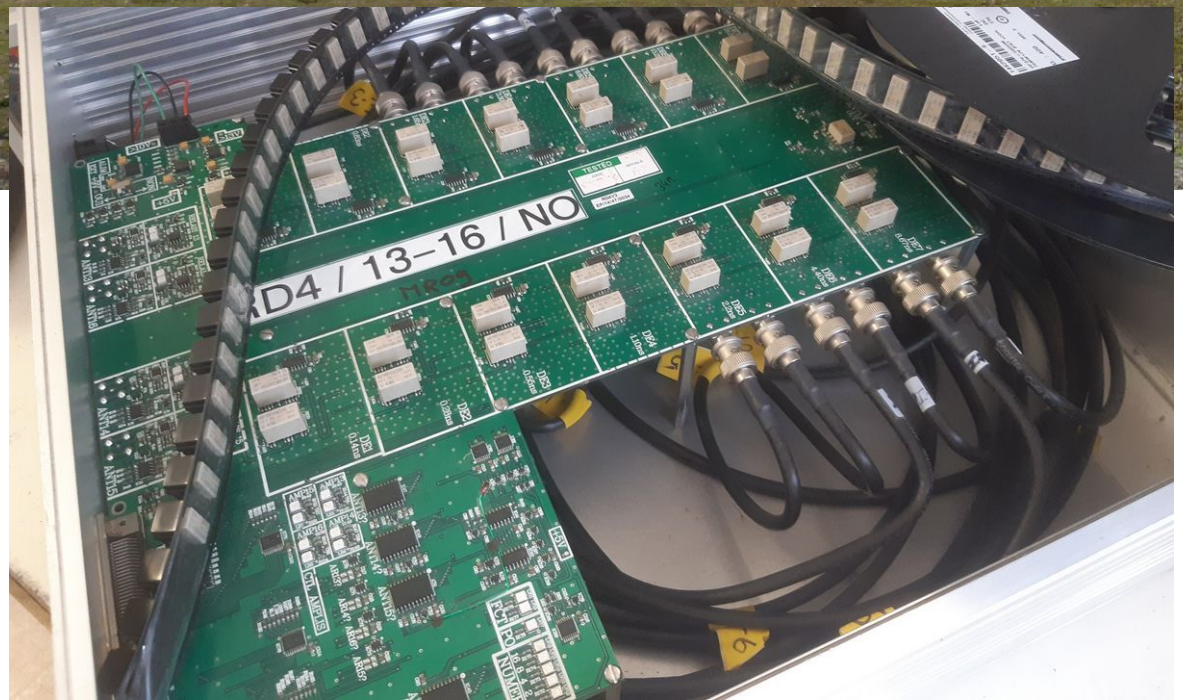

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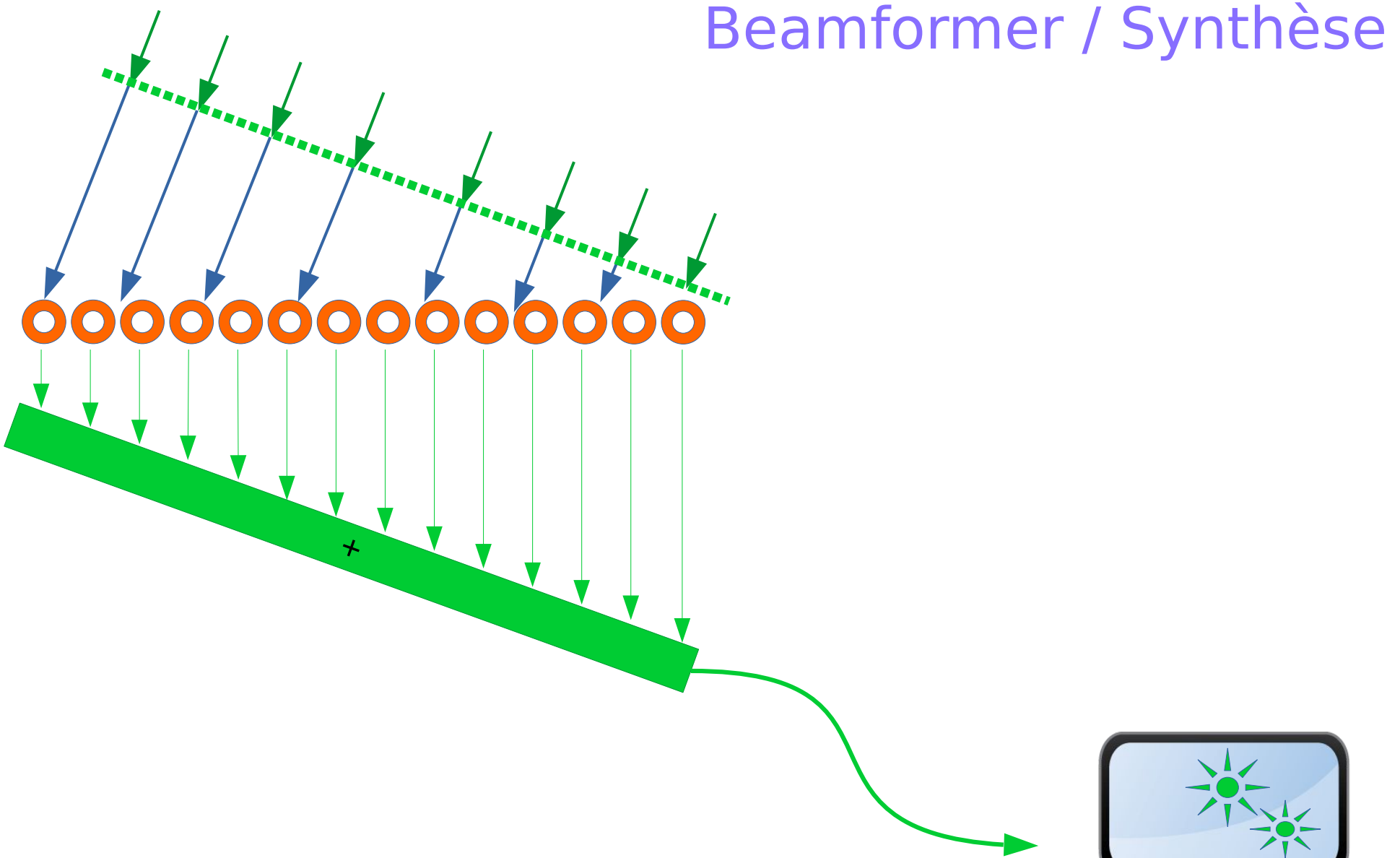
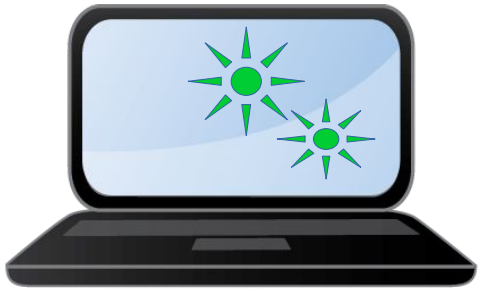
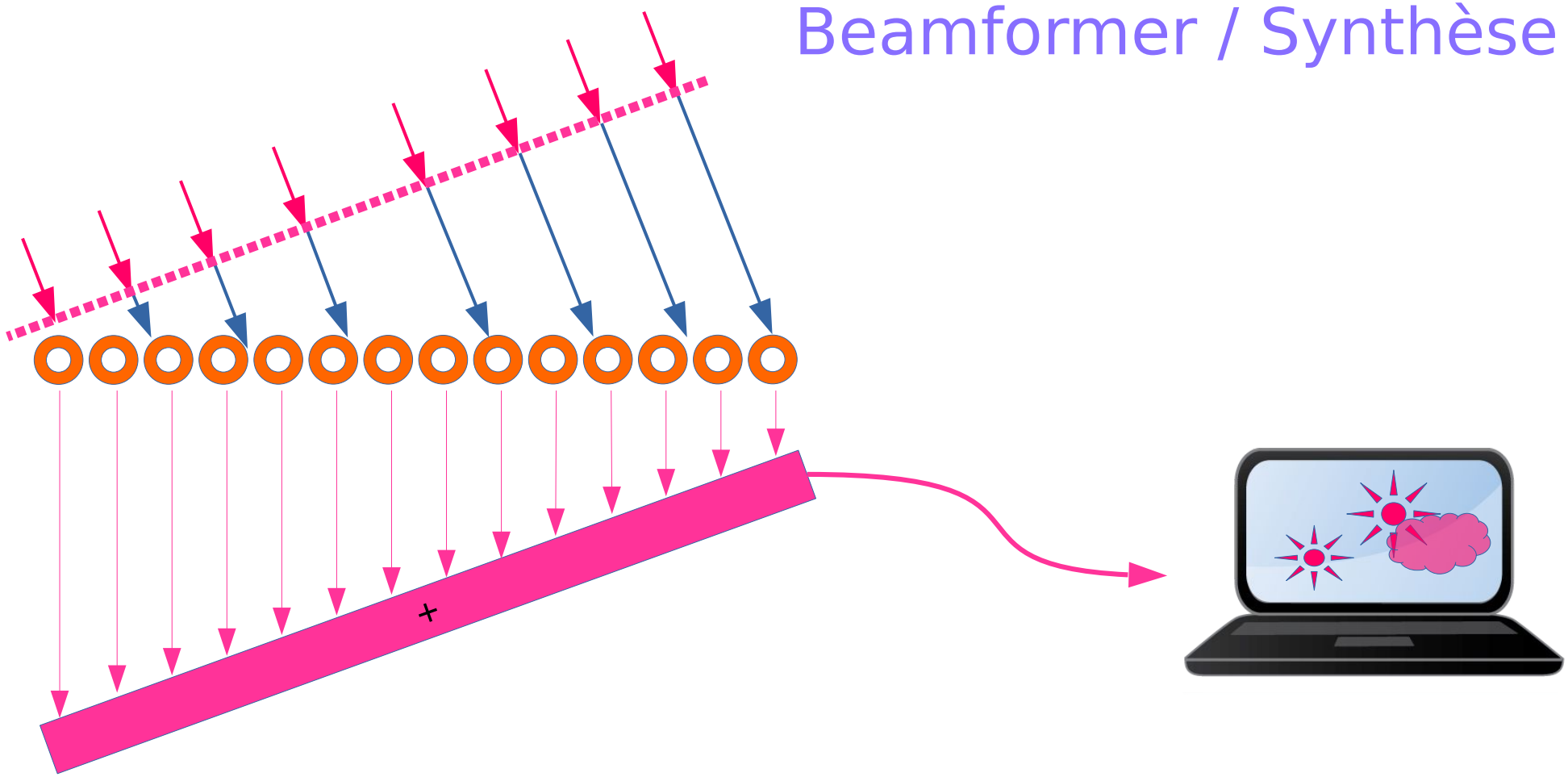
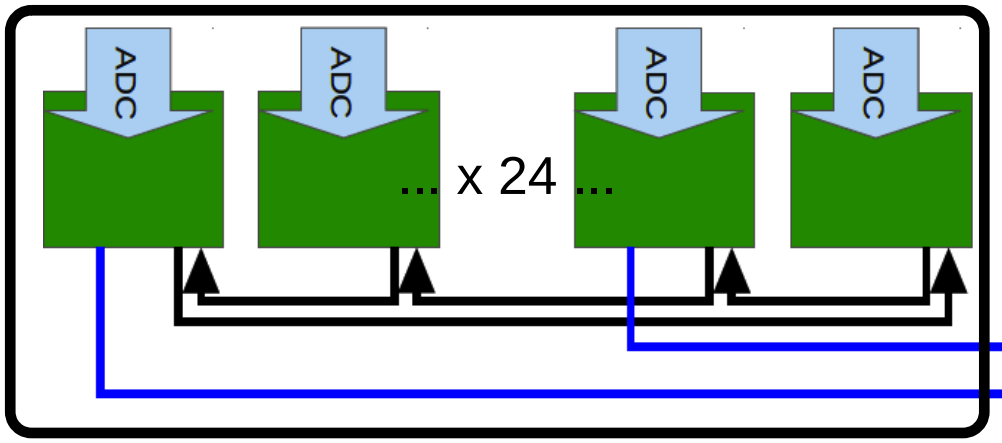
Beamformer / Synthèse de faisceau

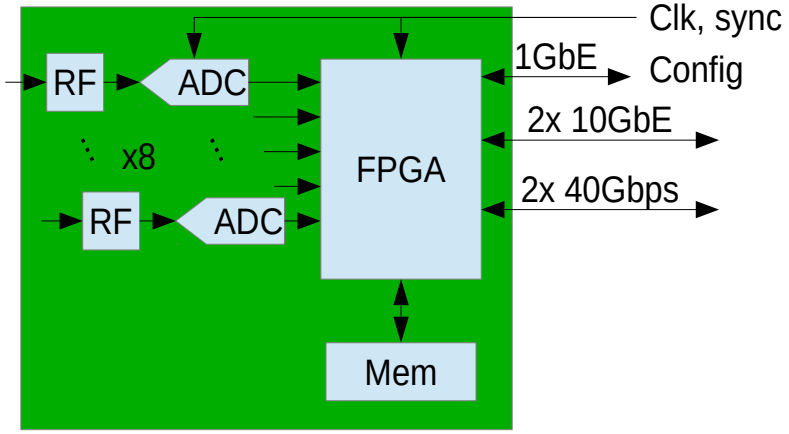




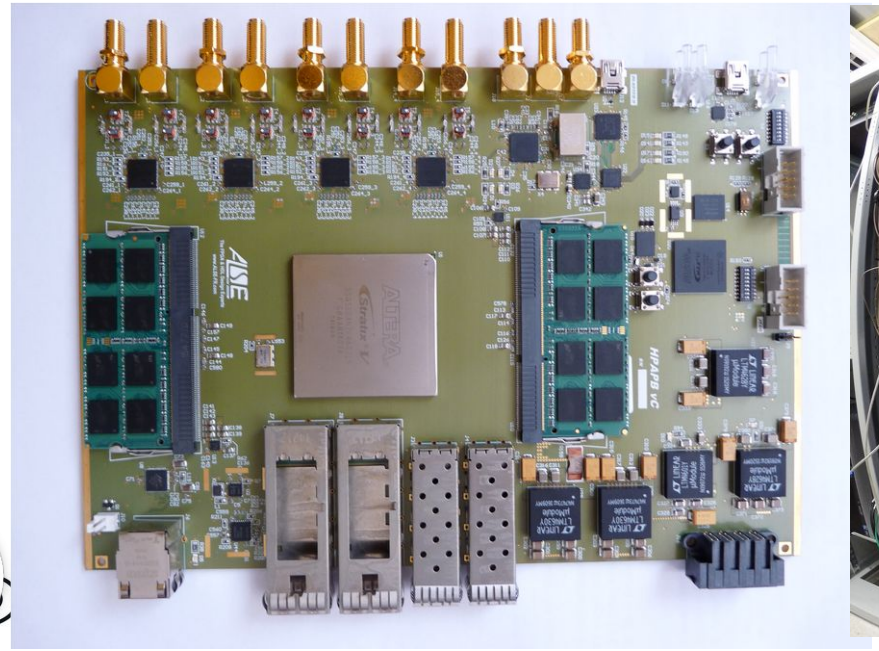
Beamformer / Synthèse de faisceau

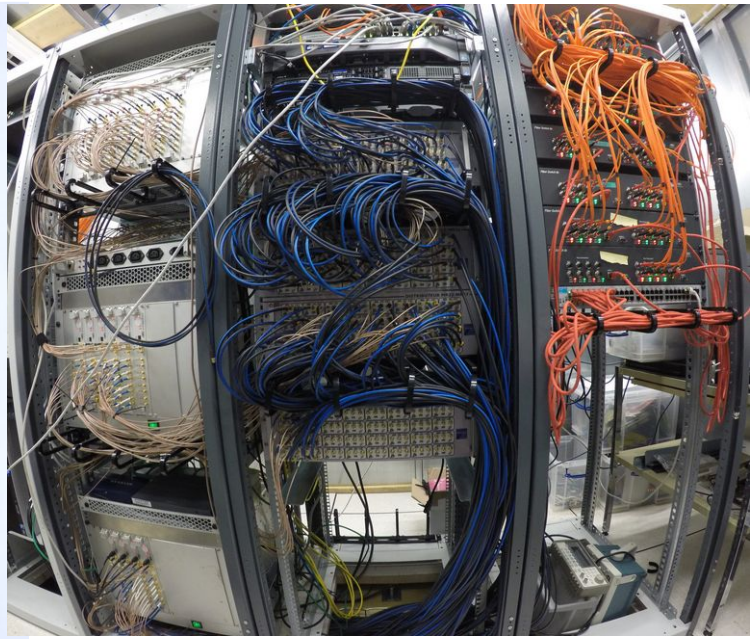




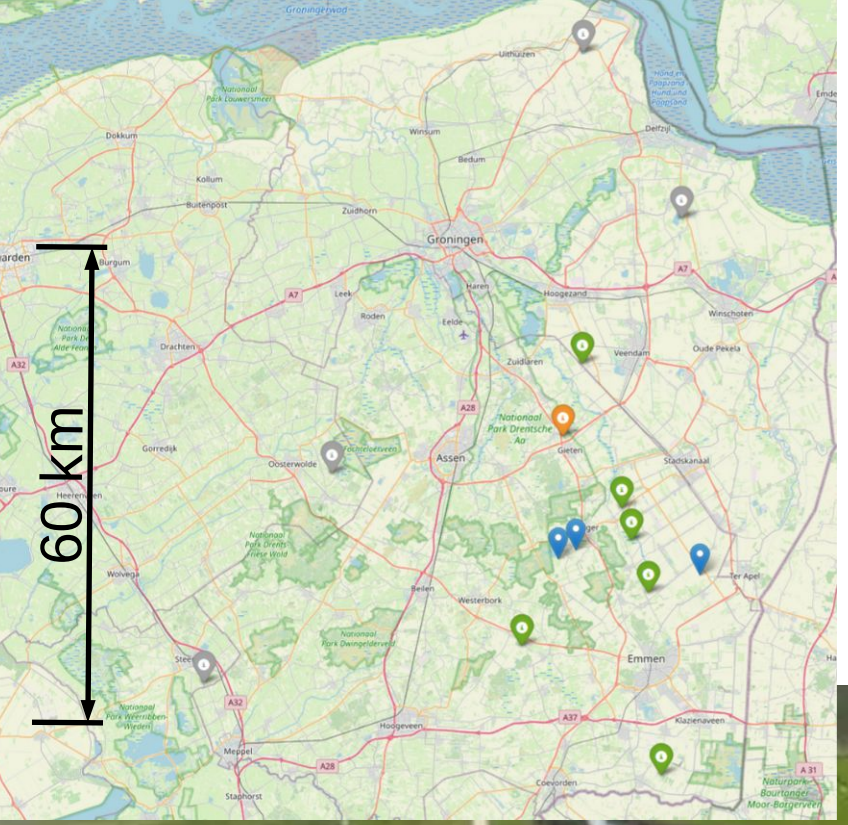


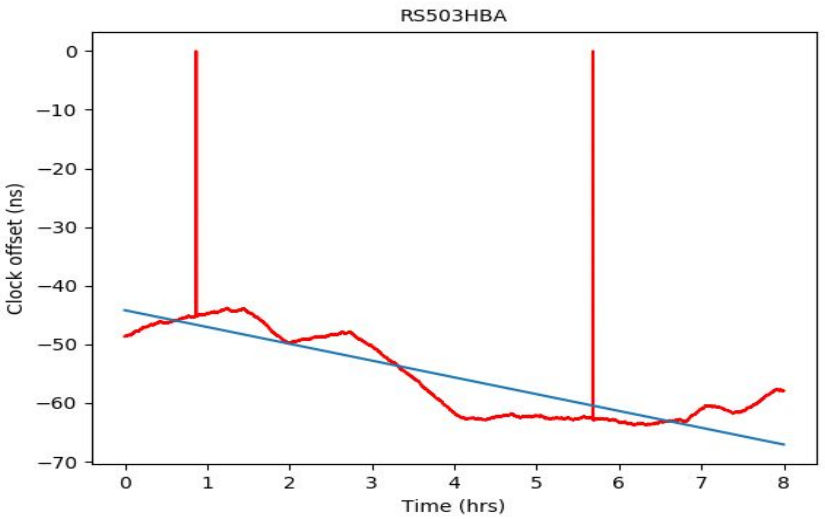
150 MHz beamformed in 10-85 MHz, full-polar.

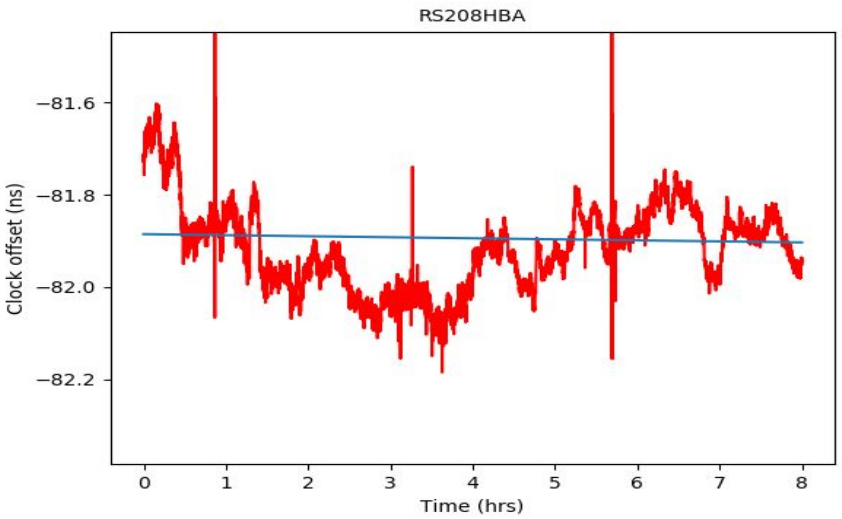




A.L.S.E
the FPGA Experts



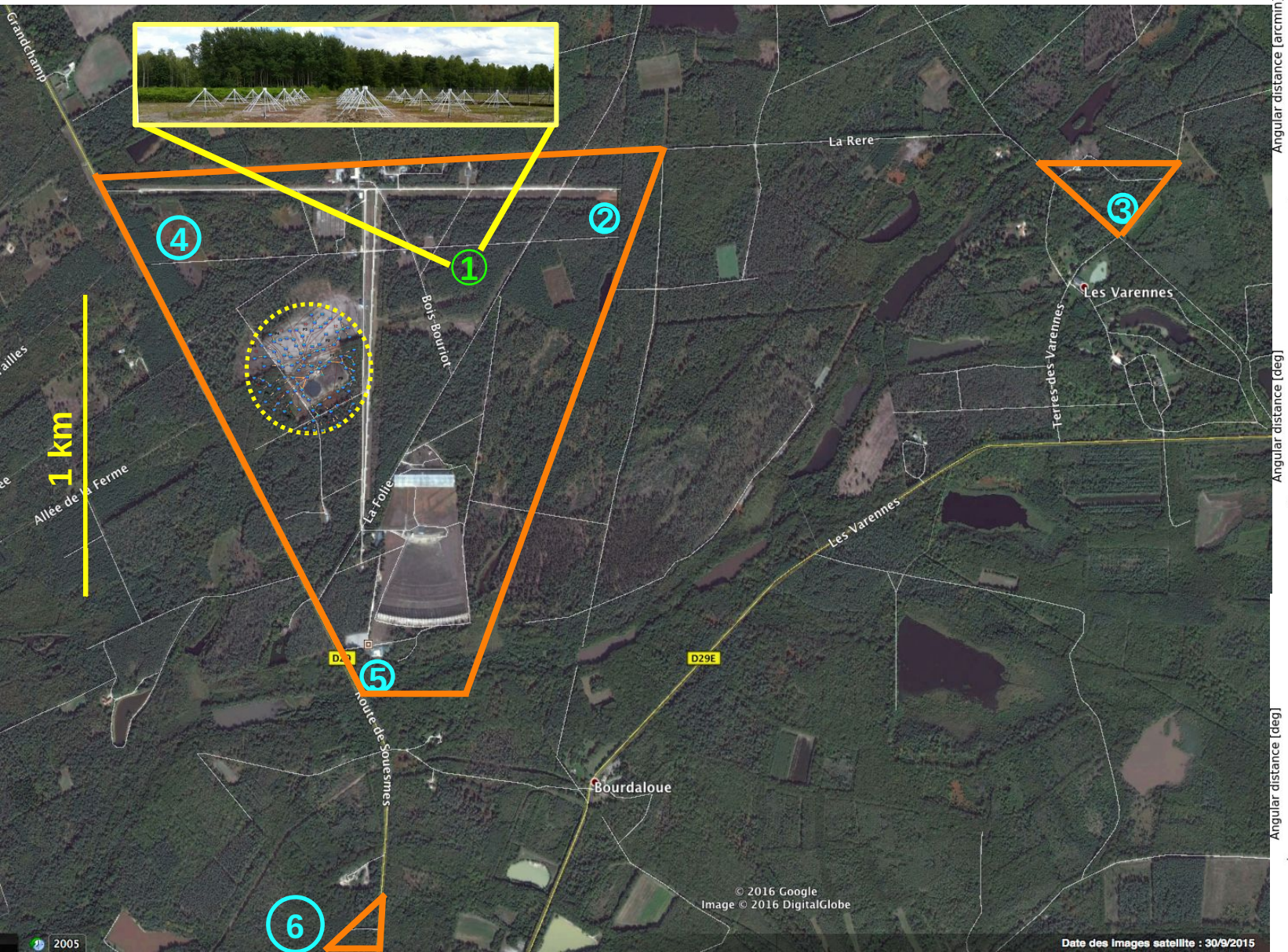


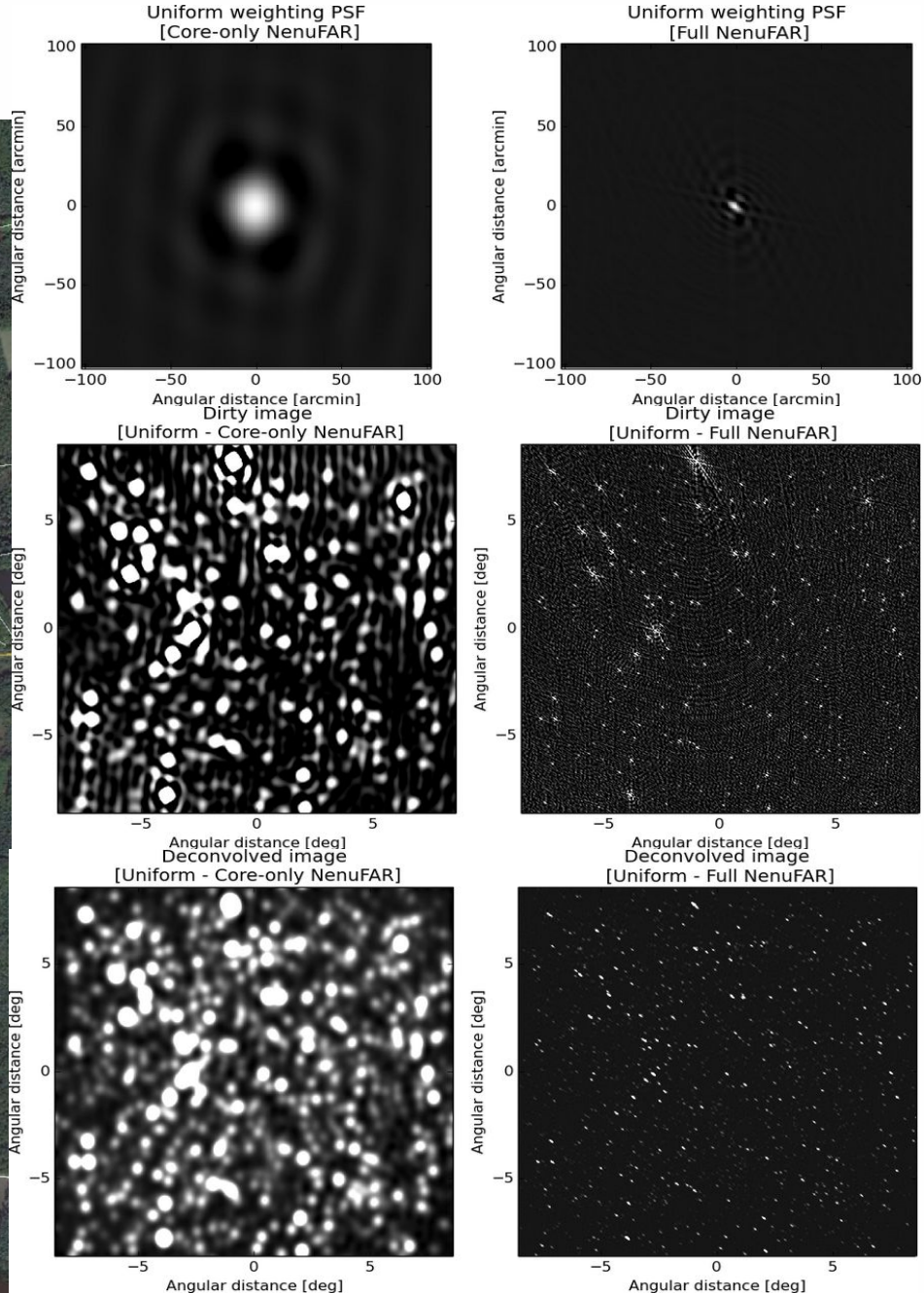


LOFAR Development Newsletter March 2024

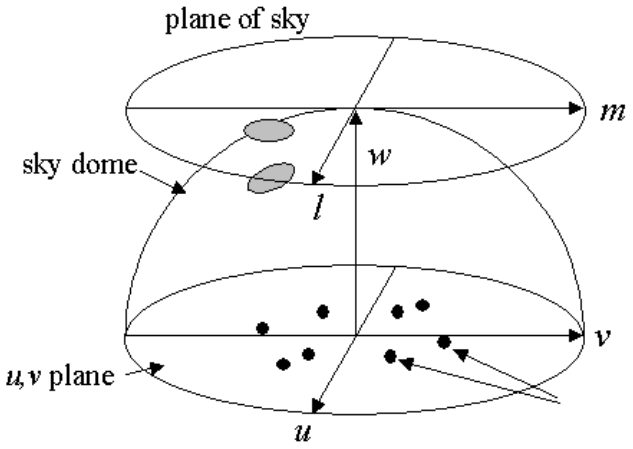
NenuFAR-Radio-Imager

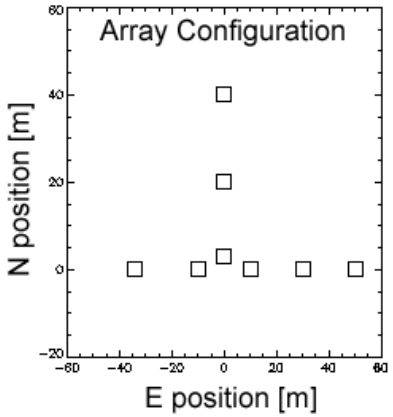
ANR «NRI» 2017-2019

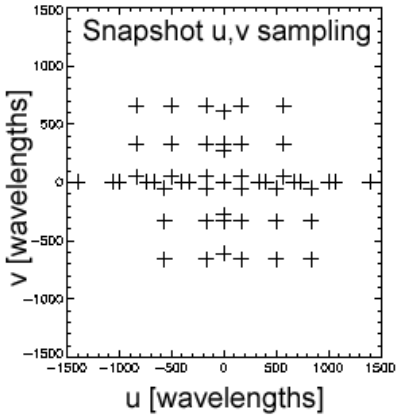


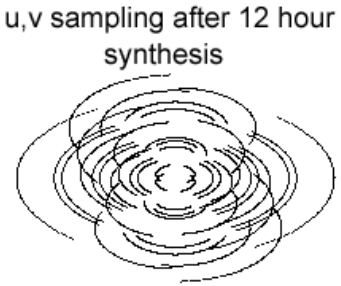


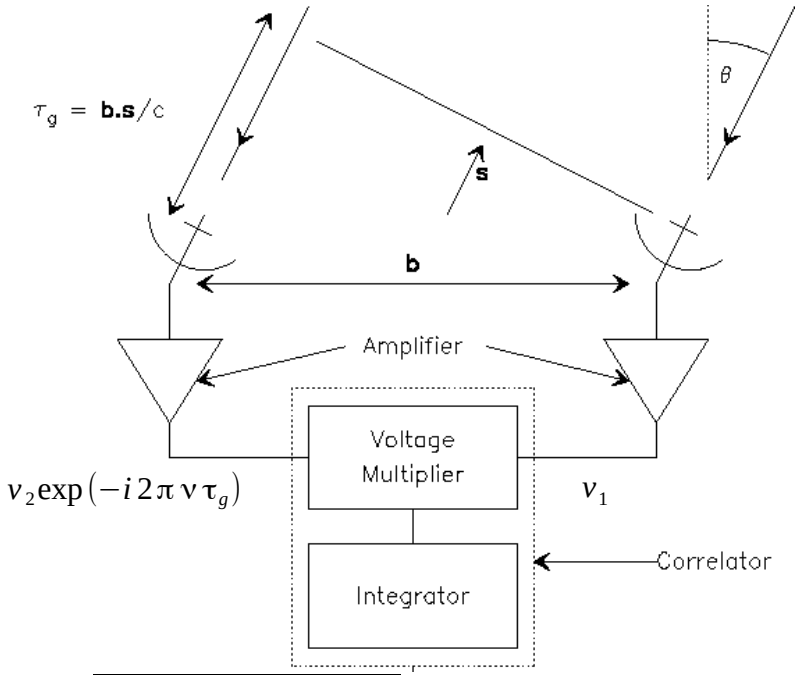
Radio Interferometry Imaging





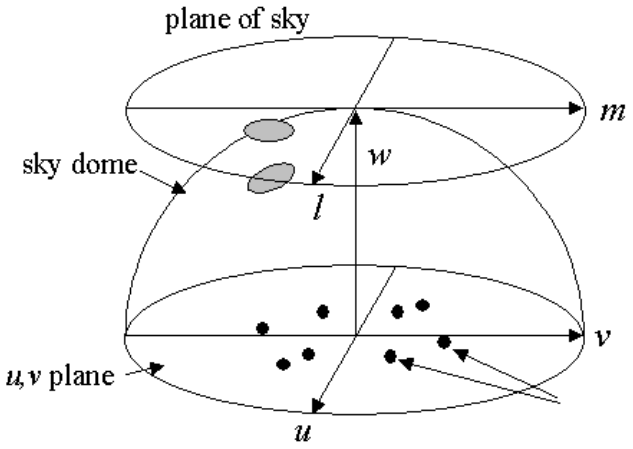


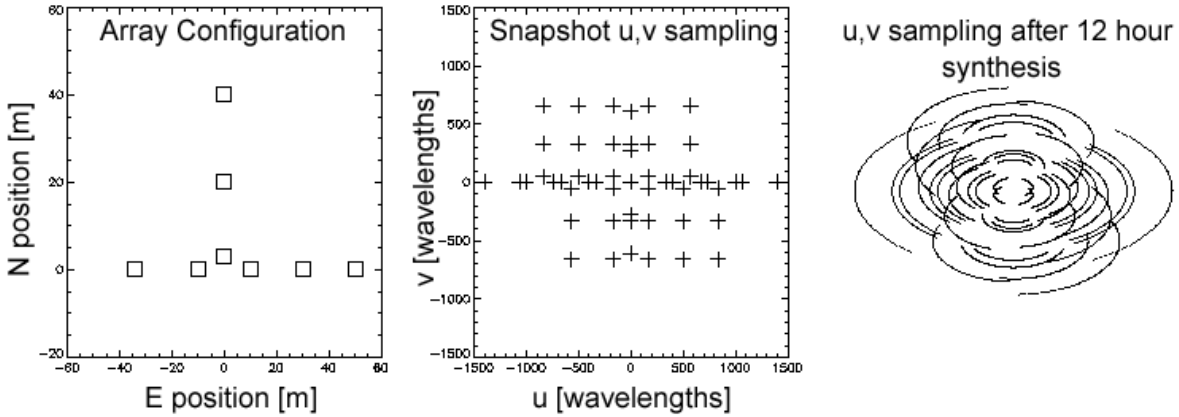


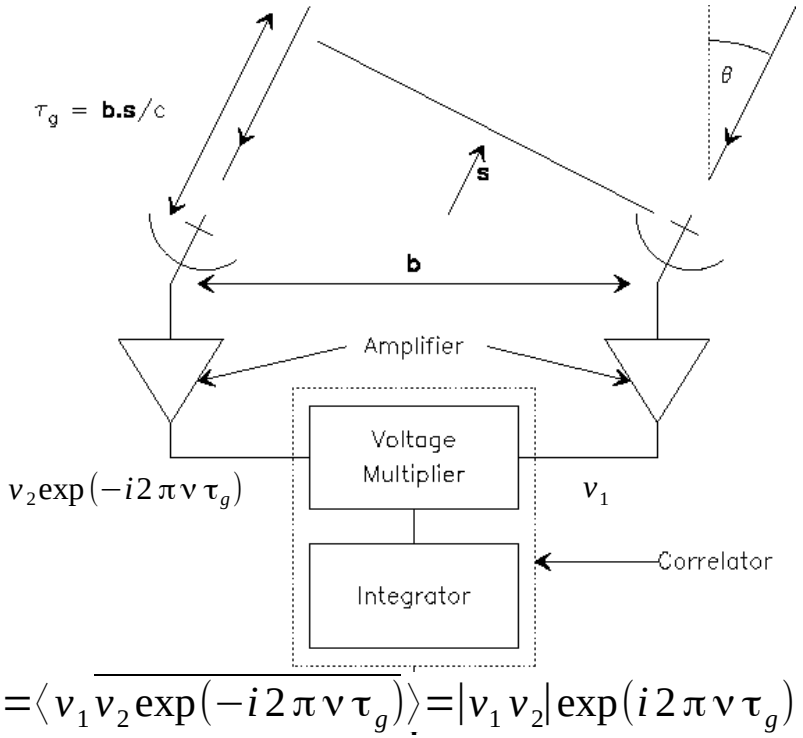


$$V = \langle v_1 \overline{v_2 \exp(-i 2\pi \nu \tau_g)} \rangle = |v_1 v_2| \exp(i 2\pi \nu \tau_g)$$

Radio Interferometry Imaging



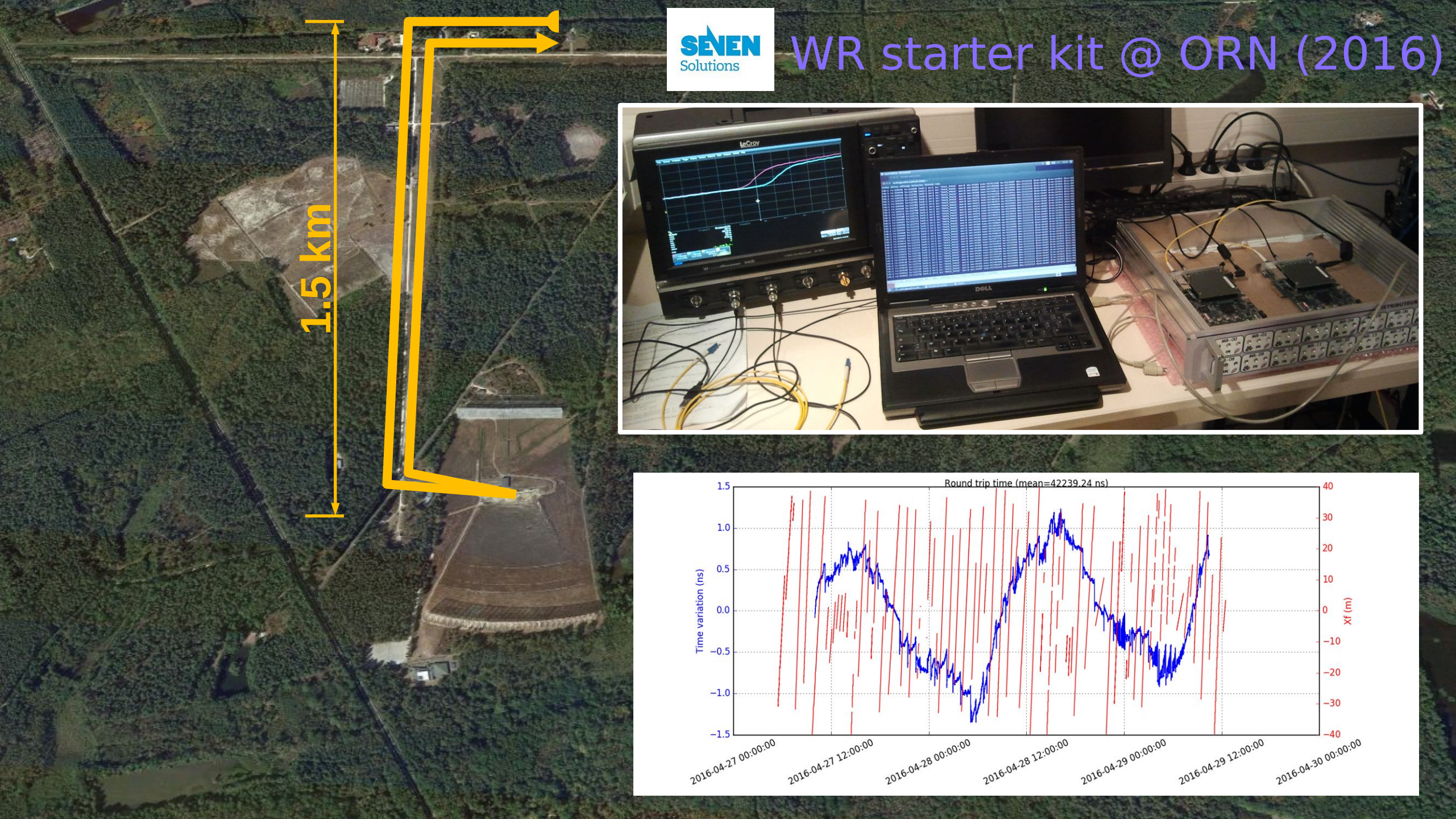




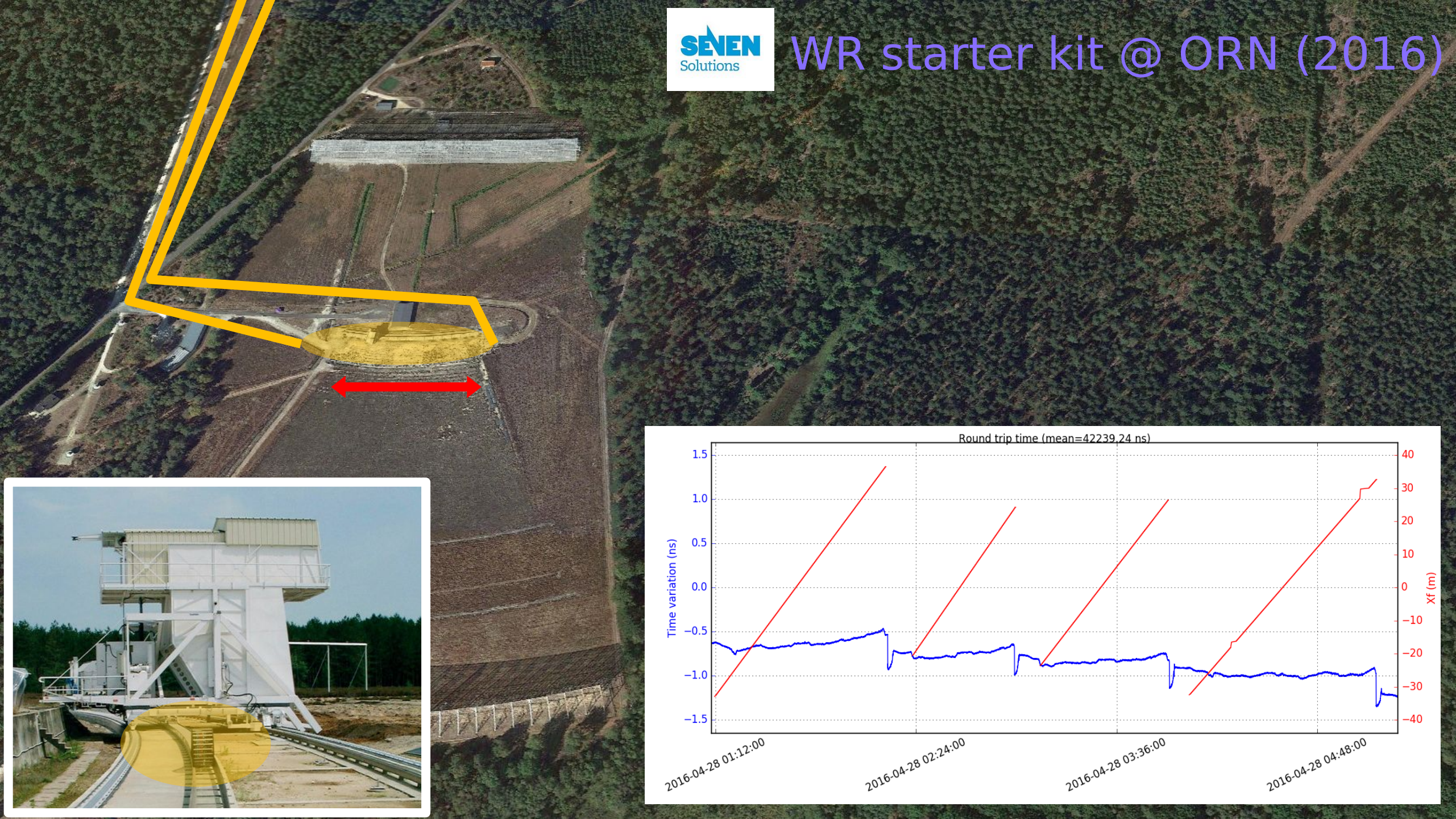
$$V = \langle v_1 \overline{v_2 \exp(-i2\pi\nu\tau_g)} \rangle = |v_1 v_2| \exp(i2\pi\nu\tau_g)$$

- Antennae/Freq transpose is costly
- N feeds → N(N+1)/2 visibilities
  - 96 MRs + 6 MRDs polarisés → 20k visibilities
- Instrumental stability required for MRDs (remote mini-arrays) → WRS + WR-LENs

WR starter kit @ ORN (2016)



WR starter kit @ ORN (2016)



SKA-mid – the SKA's mid-frequency instrument

The SKA Observatory (SKAO) is a next-generation radio astronomy facility that will revolutionise our understanding of the Universe. It will have a uniquely distributed character: **one** observatory operating **two** telescopes on **three** continents. The two telescopes, named SKA-low and SKA-mid, will be observing the Universe at different frequencies. They are also called interferometers as they each comprise a large number of individual elements working together to form a single large telescope.

Location: South Africa

Frequency range: **350 MHz** to **15.4 GHz** with a goal of 24 GHz

197 dishes (including 64 MeerKAT dishes)

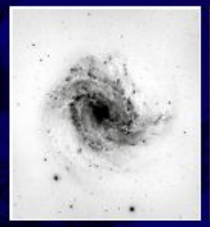
Total collecting area: **33,000m²**

or **126 tennis courts**

Maximum distance between dishes: **150km**

SKA-mid

Data transfer rate: **8.8 Terabits** per second



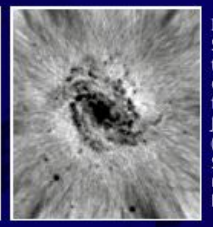


Image quality of SKA-mid (left) versus the best current facility operating in the same frequency range, the Jansky Very Large Array (JVLA) in the United States (right). SKA-mid's resolution will be 4x better than JVLA.

Compared to the JVLA, the current best similar instrument in the world:

4x the resolution

5x more sensitive

60x the survey speed

www.skatelescope.org @SKAO SKA Observatory SKA Observatory SK

SKA-low – the SKA's low-frequency instrument

The SKA Observatory (SKAO) is a next-generation radio astronomy facility that will revolutionise our understanding of the Universe. It will have a uniquely distributed character: **one** observatory operating **two** telescopes on **three** continents. The two telescopes, named SKA-low and SKA-mid, will be observing the Universe at different frequencies. They are also called interferometers as they each comprise a large number of individual elements working together to form a single large telescope.

Location: Australia

Frequency range: **50 MHz** to **350 MHz**

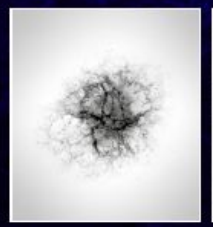
131,072 antennas spread between **512 stations**

Total collecting area: **0.4km²**

Maximum distance between stations: **>74km**

SKA-low

Data transfer rate: **7.2 Terabits** per second



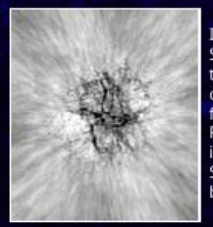


Image quality of SKA-low (left) versus the best current facility operating in the same frequency range, the LOw Frequency ARray (LOFAR), in the Netherlands (right). SKA-low's resolution will be similar to LOFAR.

Compared to LOFAR Netherlands, the current best similar instrument in the world

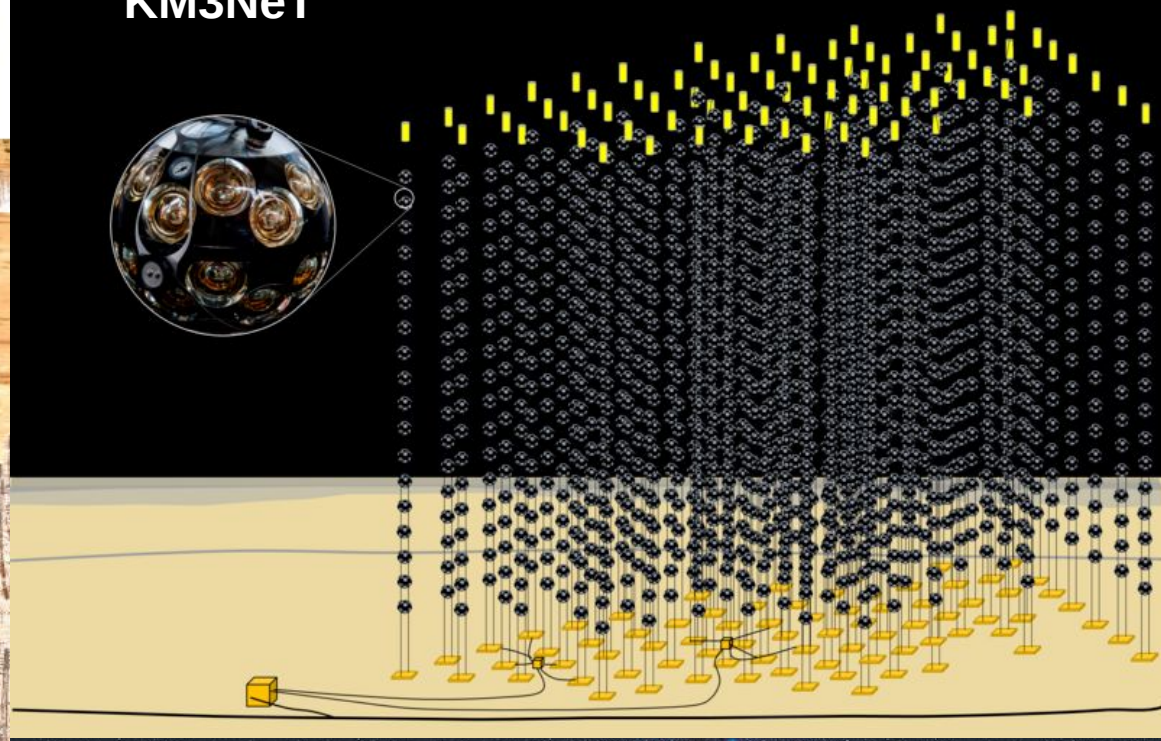
20% better resolution

8x more sensitive

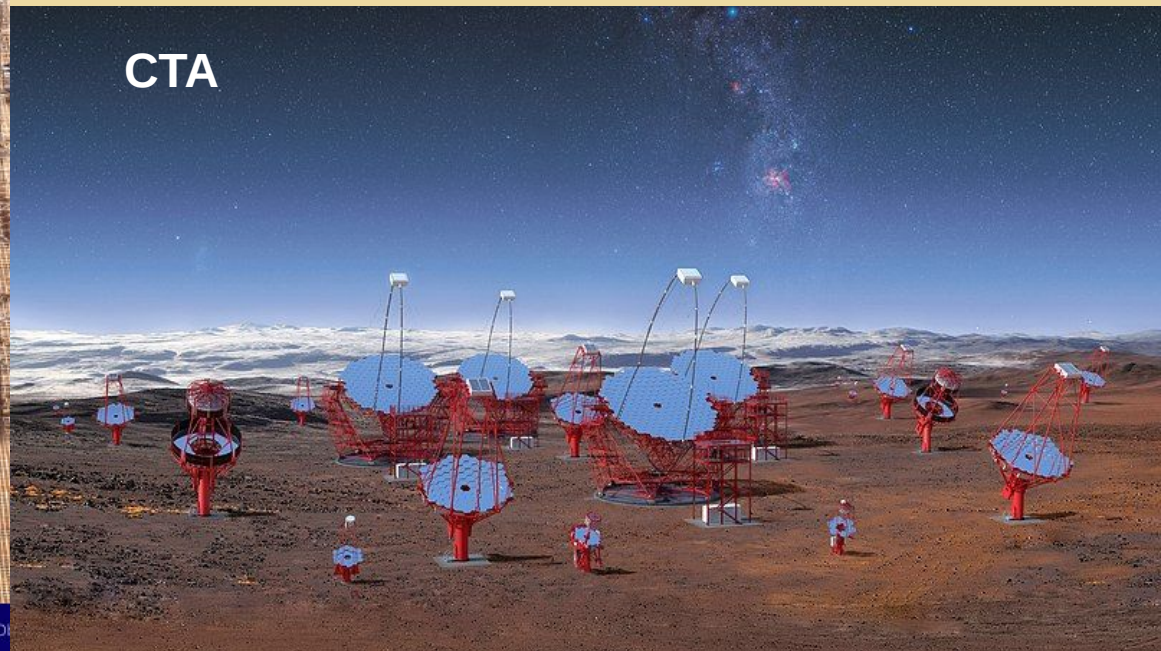
135x the survey speed

www.skatelescope.org @SKAO SKA Observatory SKA Observatory SKA O

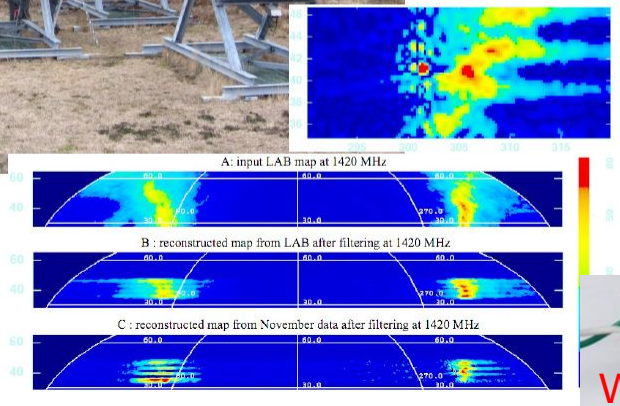
KM3NeT



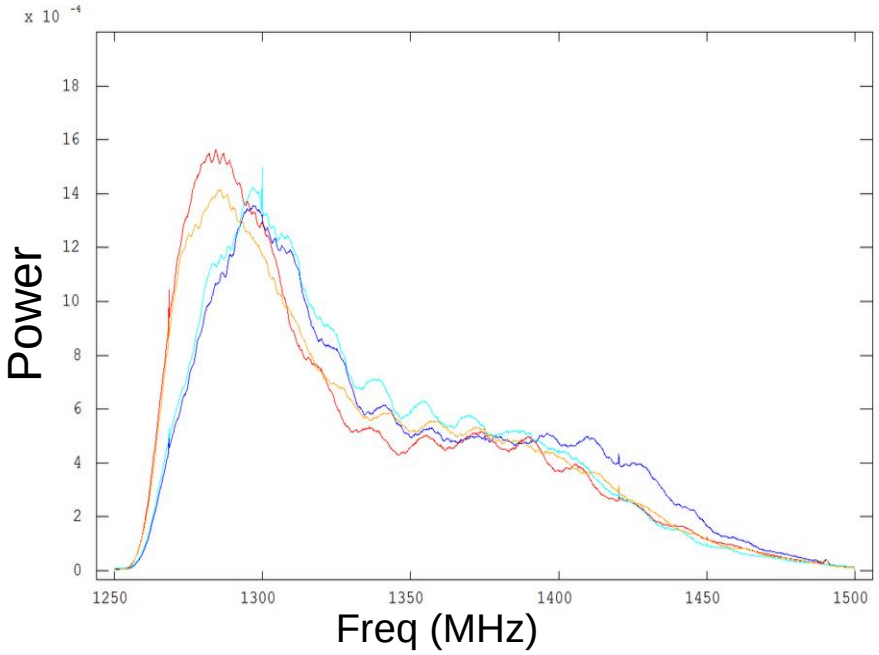
CTA

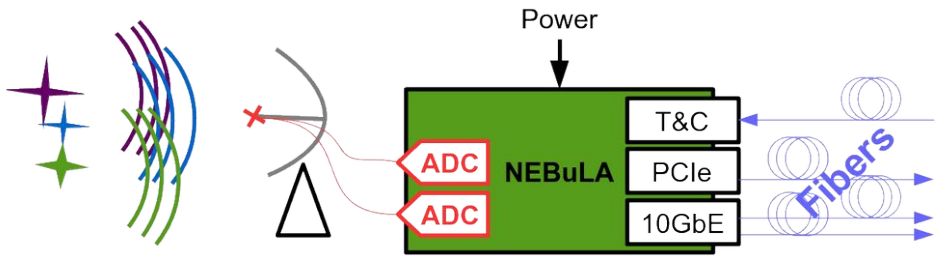


PAON IV

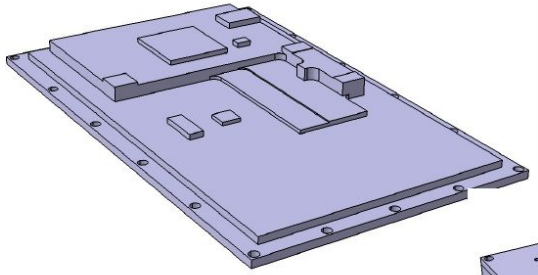


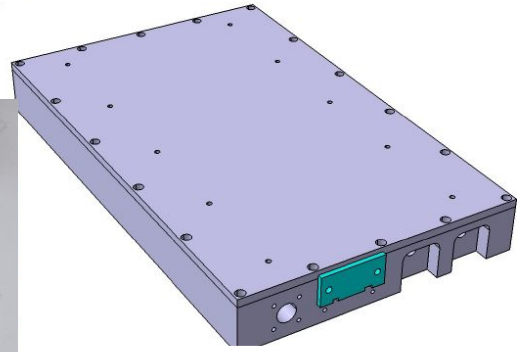
Reconstructed map at 1420.4 MHz
from PAON-4 Nov.2016 observations

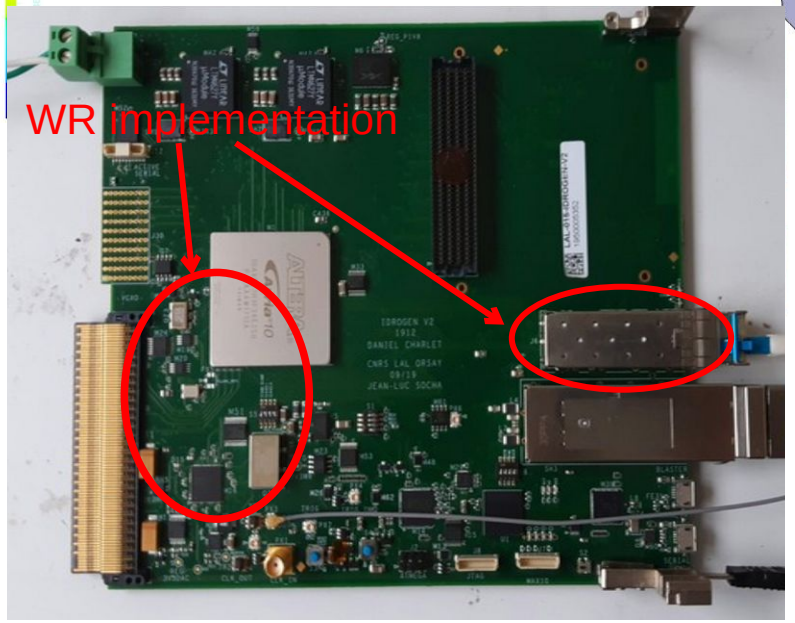




PAON IV : Mecanic for IDROGEN board



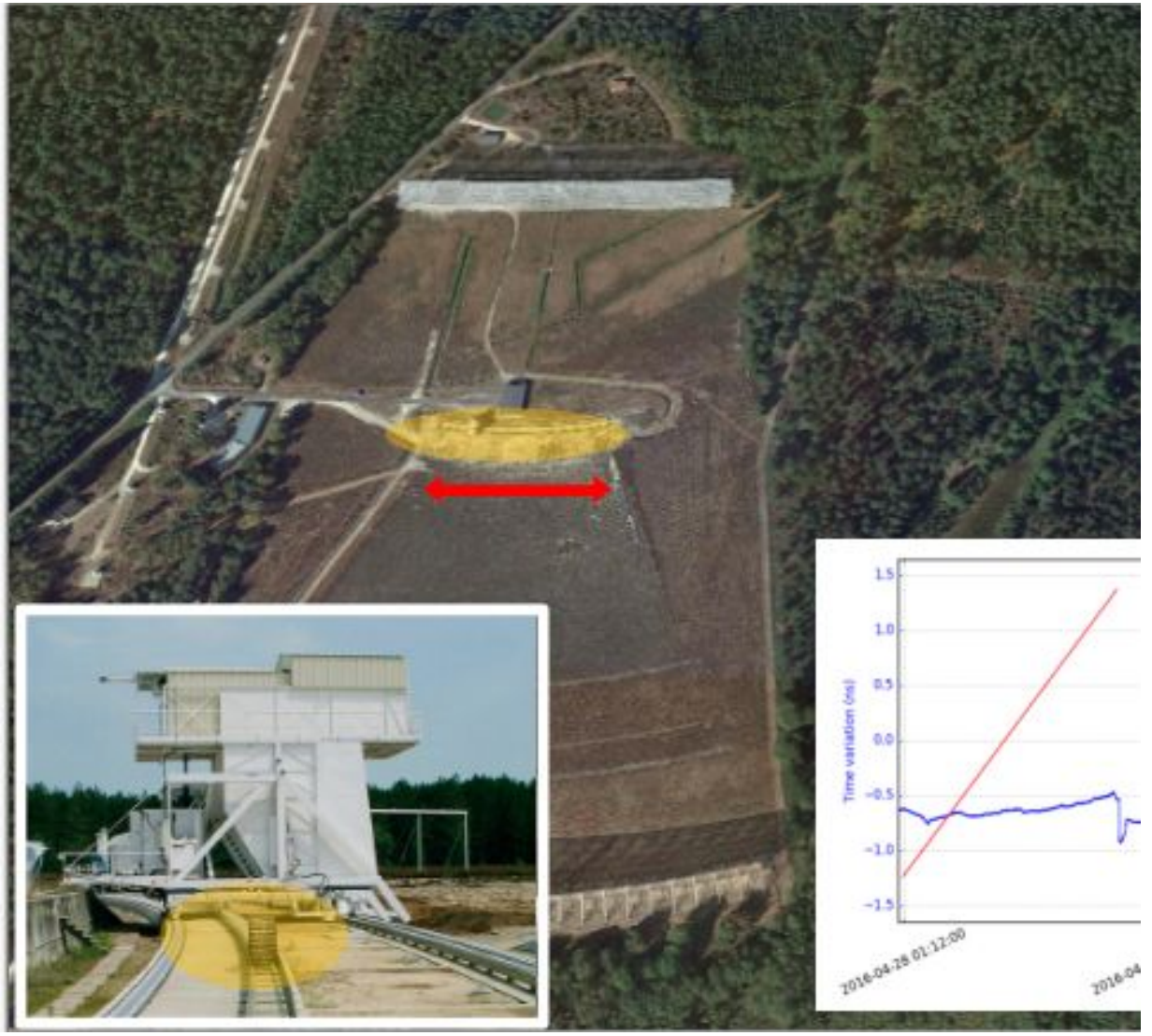




- LAL / IJCLab :
  - FPGA PCB dev
  - Soft Ctrl-Cmd
  - Firmware
- USN / ORN :
  - Firmware
  - Qualif ADC
  - Instrumentation RadioAstro
- SYRTE :
  - Métrologie Tps-Freq

Timing Pulsar au NRT

- Illustration de la variabilité du délai dans les fibres de qques 100ns (corrigé par WR)
- Et les câbles RF entre chariot et labo Hors-Champ ???
- Déplacement de la numérisation dans le chariot (+PPS/10M)
  - Augmentation de la bande
    - 500 MHz → 1.6 GHz
  - Meilleur précision de timing
    - Délai du lien mobile corrigé par WR
    - Délai du lien par T°C corrigé par WR



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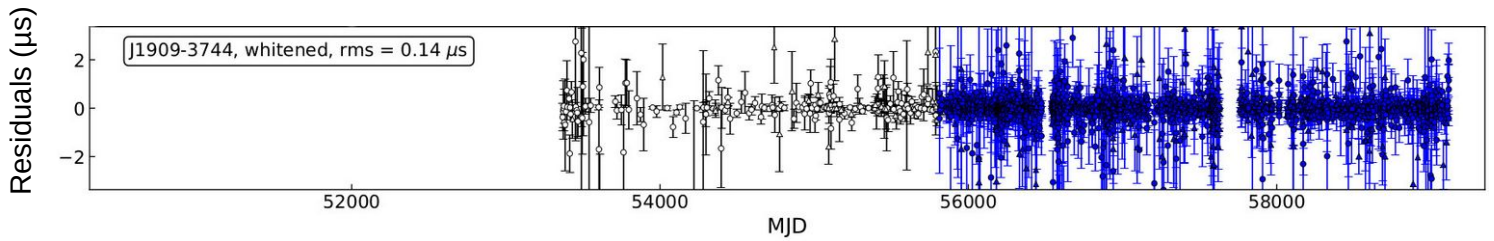
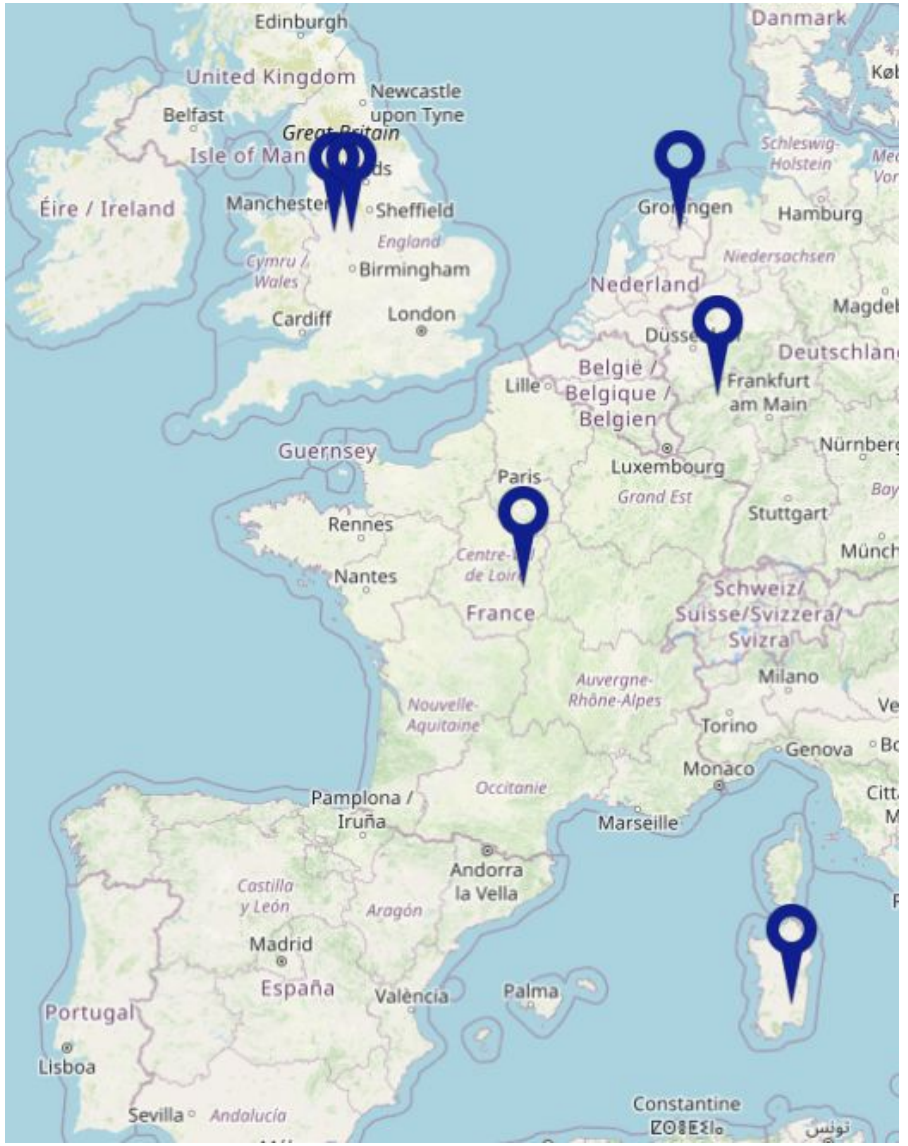
Timing Pulsar (EPTA)

- Ultra-low-frequency gravitational waves
- High-precision time-of-arrival (TOA) data for 25 MSPs (+ models) from 6 telescopes
- A common time reference would really help ! (WR over REFIMEV ?)





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- https://en.wikipedia.org/wiki/KM3NeT#/media/File:Artists-impression-km3net-detector-edw.png

Questions ?